A Comparison of different Uncertainty Activation Cross-Section Data Libraries and collapsed values for different neutron spectra: ADS, FISSION and FUSION

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Workshop on Activation Data
EAF 2011

Prague (Czech Republic), June 01 – 03, 2011

INDUSTRIALES
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OUTLINE

PART I: Cross-section uncertainties under different neutron spectra

1. **ADS**
2. **PWR**
3. **DEMO**

Using EAF-2007, EAF-2010 and SCALE-6.0

(relative error, Δ)~ $\Delta_{I=1,EXP}$= $\Delta_{I=1,EAF}$/3

PART II: Processing uncertainty libraries

1. **245Cm(n,g)**
2. **240Pu(n,g)**

INTRODUCTION. The context of this work …

Annals of Nuclear Energy 37 (2010) 1570–1579

Contents lists available at ScienceDirect

Annals of Nuclear Energy

journal homepage: www.elsevier.com/locate/anucene

Nuclear data requirements for the ADS conceptual design EFIT: Uncertainty and sensitivity study

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A R T I C L E I N F O

Article history:
Received 21 January 2010
Received in revised form 10 June 2010
Accepted 10 June 2010
Available online 4 July 2010

Keywords:
ADS
Cross-section uncertainties
Uncertainty propagation
Sensitivity technique
Monte Carlo simulation
Target accuracies

A B S T R A C T

In this paper, we assess the impact of activation cross-section uncertainties on relevant fuel cycle parameters for a conceptual design of a modular European Facility for Industrial Transmutation (EFIT) with a "double strata" fuel cycle. Next, the nuclear data requirements are evaluated so that the parameters can meet the assigned design target accuracies. Different discharge burn-up levels are considered: a low burn-up, corresponding to the equilibrium cycle, and a high burn-up level, simulating the effects on the fuel of the multi-recycling scenario.

In order to perform this study, we propose a methodology in two steps. Firstly, we compute the uncertainties on the system parameters by using a Monte Carlo simulation, as it is considered the most reliable approach to address this problem. Secondly, the analysis of the results is performed by a sensitivity technique, in order to identify the relevant reaction channels and prioritize the data improvement needs. Cross-section uncertainties are taken from the EAF-2007/UN library since it includes data for all the actinides potentially present in the irradiated fuel.

Relevant uncertainties in some of the fuel cycle parameters have been obtained, and we conclude with recommendations for future nuclear data measurement programs, beyond the specific results obtained with the present nuclear data files and the limited available covariance information. A comparison with the uncertainty and accuracy analysis recently published by the WPEC-Subgroup26 of the OECD using BOLNA covariance matrices is performed. Despite the differences in the transmuter reactor used for the analysis, some conclusions obtained by Subgroup26 are qualitatively corroborated, and improvements for additional cross sections are suggested.

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- **Within the frame of EUROTRANS-ADS project**
- **ADS conceptual design EFIT fuel cycle**
- **Uncertainty and Sensitivity study throughout fuel cycle**
- **Identifying critical XS in order to reduce uncertainties**

INTRODUCTION. The context of this work …

Nuclear Science
NEA/WPEC-26

ISBN 978-92-64-99053-1

International Evaluation Co-operation

VOLUME 26

UNCERTAINTY AND TARGET ACCURACY ASSESSMENT FOR INNOVATIVE SYSTEMS USING RECENT COVARIANCE DATA EVALUATIONS

A report by the Working Party on International Evaluation Co-operation of the NEA Nuclear Science Committee

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NEA No. 6410

NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

- **Working Party on Evaluation Co-operation (WPEC) Subgroup 26**
- **Systematic approach to define data needs for advanced reactor systems**
- **Advanced reactor systems:**
  - ABTR, SFR, EFR, VHTR
  - GFR, LFR, ADMAB
  - **PWR** (high burn-up)
- **Identifying critical XS in order to reduce uncertainties**

ADS Uncertainty Requirements

Table. **Critical cross-section uncertainties collapsed in one-group and processed from EAF2007/UN (Δ_{EAF}) and their target accuracies (Δ_{target})**

500GWd/tHM burn-up

Reaction		Δ_{EAF}	Δ_{TARGET}
U^{234}	(n, γ)	38.9	7.1
	$(n, \gamma - M)$	38.9	7.1
U^{235}	Fission	12.9	4.2
Np^{237}	(n, γ)	14.3	2.8
Pu^{238}	Fission	12.3	6.4
	(n, γ)	14.5	5.2
Pu^{239}	Fission	9.6	3.4
Pu^{240}	(n, γ)	9.3	4.8
Pu^{241}	Fission	15.6	4.2
Pu^{242}	(n, γ)	12.6	5.3
Am^{241}	(n, γ)	15.8	2.8
	$(n, \gamma - M)$	15.9	2.9
Am^{242m}	Fission	24.0	2.4
	(n, γ)	32.8	6.2
Am^{243}	$(n, \gamma - M)$	15.3	4.1
Cm^{242}	(n, γ)	30.0	3.4
Cm^{243}	Fission	16.0	3.2
	(n, γ)	32.0	7.4
Cm^{244}	(n, γ)	24.6	4.6
Cm^{245}	Fission	9.7	4.1
	(n, γ)	32.7	5.5
Cm^{246}	(n, γ)	28.2	4.3
Cm^{247}	Fission	16.5	4.0
	(n, γ)	32.1	5.0
Cm^{248}	(n, γ)	19.2	2.5
Bk^{249}	(n, γ)	31.7	3.2
Cf^{249}	(n, γ)	32.4	4.3
Cf^{250}	Fission	33.0	6.9
	(n, γ)	29.3	2.6
Cf^{251}	Fission	31.6	3.7
	(n, γ)	29.9	2.4

- **Target of required accuracies**

  1) Uncertainty in the **concentration of all the nuclides of interest** **<5%**
  2) Uncertainty in the **response functions in the cooling times (decay heat, radiotoxicity, neutron emission, …)** **<10%**

- **List of priorities**

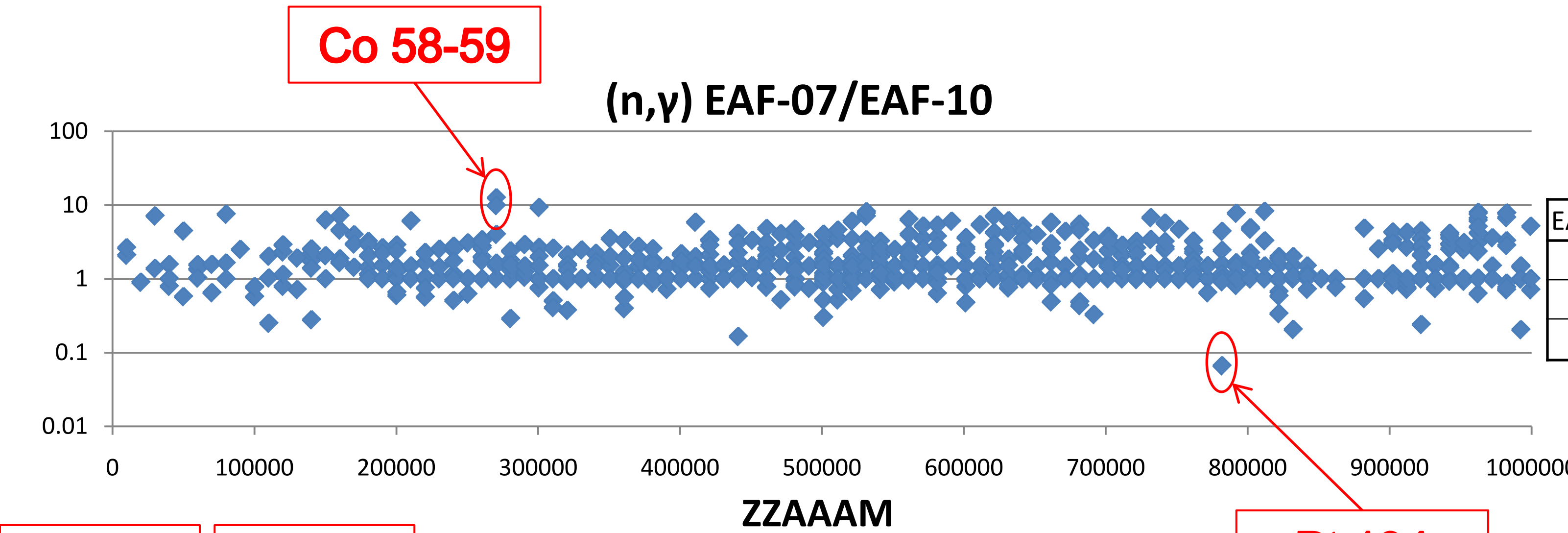
➢ Fission cross sections of ^{242m}Am, ^{243}Cm, ^{250,251}Cf
➢ (n, γ) of ^{234}U, ^{237}Np, ^{241,242m}Am, ^{242,244,245,246,247,248}Cm, ^{249}Bk, ^{249,250,251}Cf
➢ (n, γ-M) of ^{234}U, ^{241}Am

ADS Uncertainty collapsed in one energy group

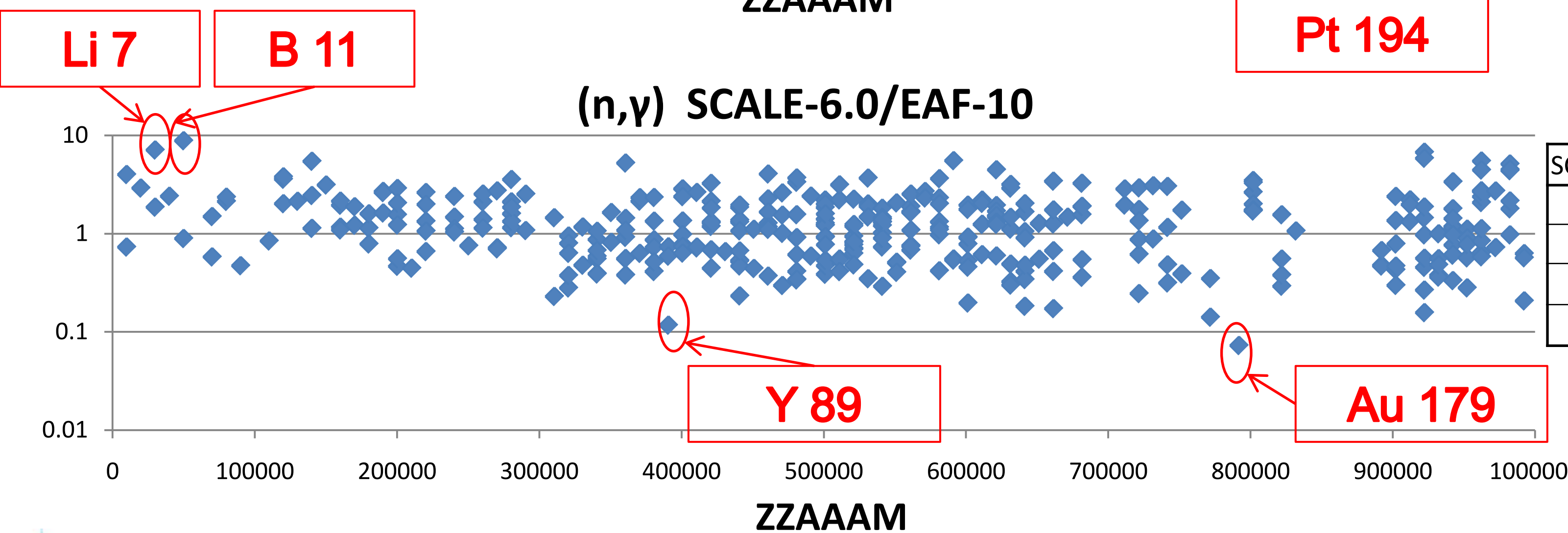
Table. One-group uncertainties in the critical cross-sections processed from EAF2007/UN (3-4 groups), EAF2010/UN(3-4 groups) and SCALE6.0-COVA (44 groups). Calculations correspond to a burn-up of 500GWd/tHM.

	(n,fission)				(n,γ)				(n,γ-M)			
Isotope	EAF2007	EAF2010	SCALE6.0	TARGET	EAF2007	EAF2010	SCALE6.0	TARGET	EAF2007	EAF2010	SCALE6.0	TARGET
234U	16.5	16.5	30.0		38.9	26.0	**6.9**	**7.1**	38.9	26.0	-	**7.1**
235U	12.9	**5.5**	**0.4**	**4.2**	11.3	3.2	21.8		-	-	-	
236U	15.9	15.3	27.2		8.9	3.2	3.1		-	-	-	
238U	16.6	16.6	0.5		6.7	3.2	1.4		-	-	-	
237Np	16.7	16.4	6.6		14.3	9.1	**3.3**	**2.8**	-	-	-	
238Pu	12.4	**10.1**	**10.6**	**6.4**	14.5	**3.7**	**6.6**	**5.2**	-	-	-	
239Pu	9.6	7.9	**0.4**	**3.4**	12.5	4.2	4.8		-	-	-	
240Pu	15.8	14.7	0.6		9.3	**3.6**	**1.2**	**4.8**	-	-	-	
241Pu	15.6	**5.6**	**1.2**	**4.2**	15.4	5.2	4.0		-	-	-	
242Pu	16.5	16.5	3.4		12.6	**3.5**	**5.0**	**5.3**	-	-	-	
244Pu	16.5	16.5	19.0		30.4	7.4	24.9		-	-	-	
241Am	16.6	16.6	2.2		15.8	16.7	**4.7**	**2.8**	15.8	16.7	-	**2.9**
242MAm	16.5	5.6	9.8	**2.4**	32.8	13.2	14.5	**6.2**	-	-	-	
243Am	16.6	16.0	5.8		15.3	5.0	4.5		15.3	**3.8**	-	**4.1**
242Cm	16.5	16.5	31.9		30.0	12.9	10.8	**3.4**	-	-	-	
243Cm	16.0	**5.9**	19.7	**3.2**	32.0	**5.2**	14.2	**7.4**	-	-	-	
244Cm	16.4	14.8	37.0		24.6	**3.7**	**7.7**	**4.6**	-	-	-	
245Cm	9.8	11.3	20.2	**4.1**	32.8	**4.1**	**9.8**	**5.5**	-	-	-	
246Cm	16.6	15.2	8.0		28.2	**3.7**	20.3	**4.3**	-	-	-	
247Cm	16.5	16.5	11.3	**4.0**	32.1	**7.7**	20.6	**5.0**	-	-	-	
248Cm	16.2	15.3	16.2		19.2	**3.8**	16.9	**2.5**	-	-	-	
249Bk	16.6	16.6	22.5		31.7	8.8	23.7	**3.2**	-	-	-	
249Cf	16.3	5.8	19.3		32.4	**4.8**	24.5	**4.3**	-	-	-	
250Cf	33.0	33.0	**13.3**	**6.9**	29.3	9.0	16.0	**2.6**	-	-	-	
251Cf	31.6	12.9	21.9	**3.7**	30.0	**3.9**	16.6	**2.4**	-	-	-	
252Cf	15.0	10.7	6.1		31.2	4.0	18.1		-	-	-	

ADS Uncertainty collapsed in one energy group

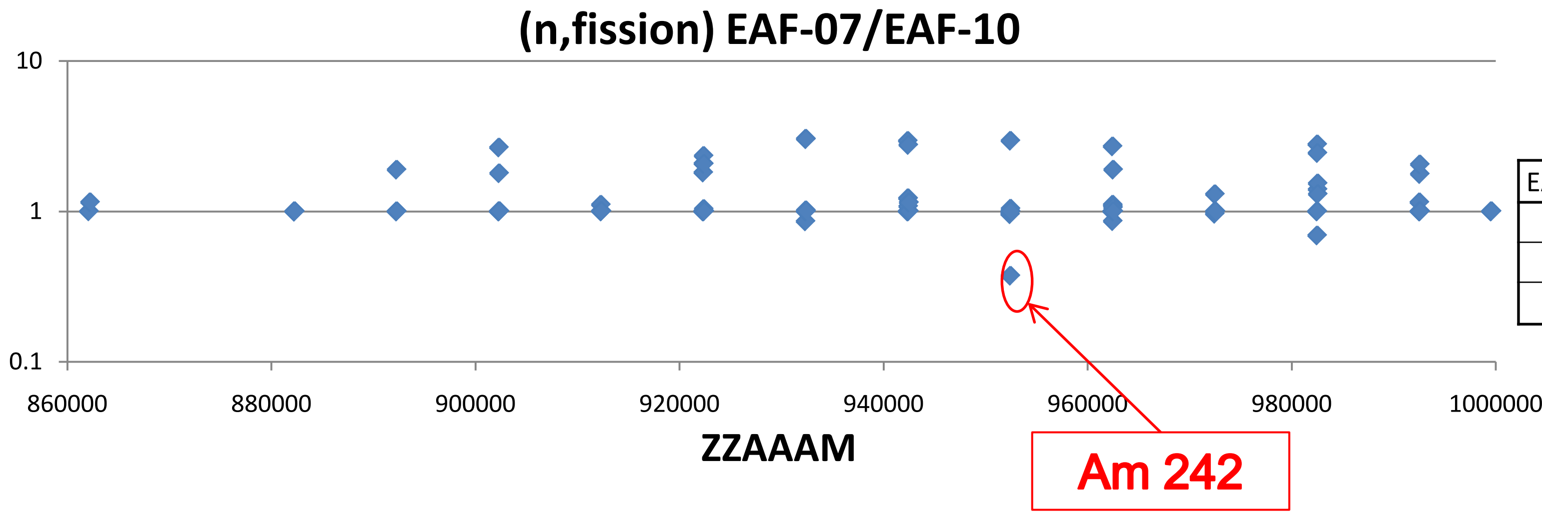


EAF-07/EAF-10	Statistics (%)
f=1	26.85
f<1	12.68
f>1	60.47

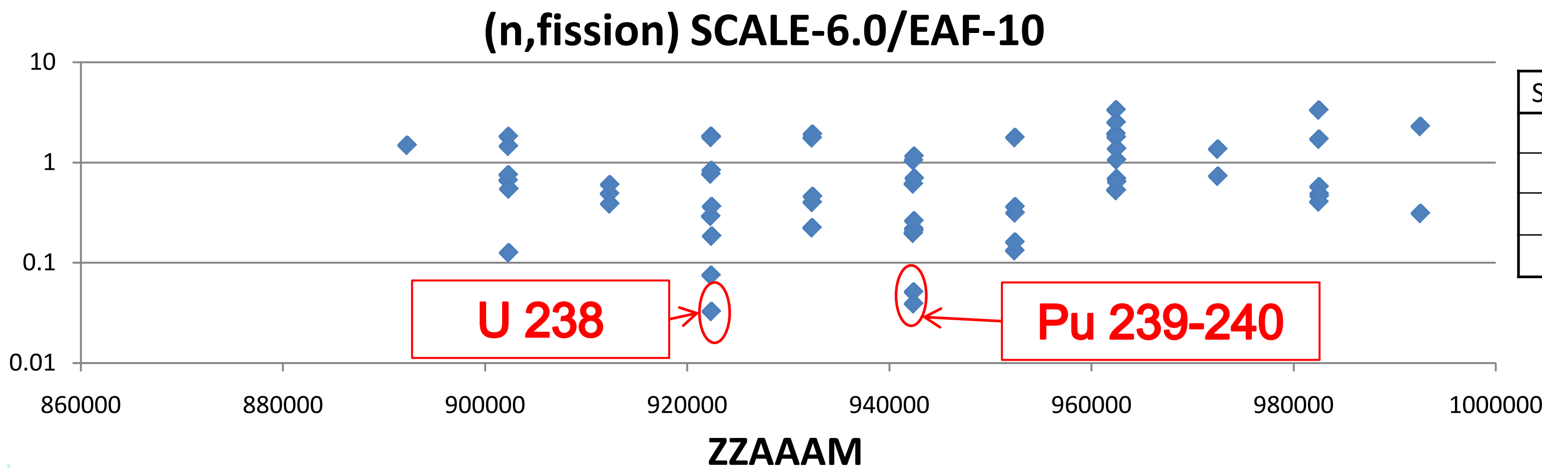


SCALE/EAF-10	Statistics (%)
f=1	0.00
f=0	53.69
0<f<1	20.20
f>1	26.11

ADS Uncertainty collapsed in one energy group

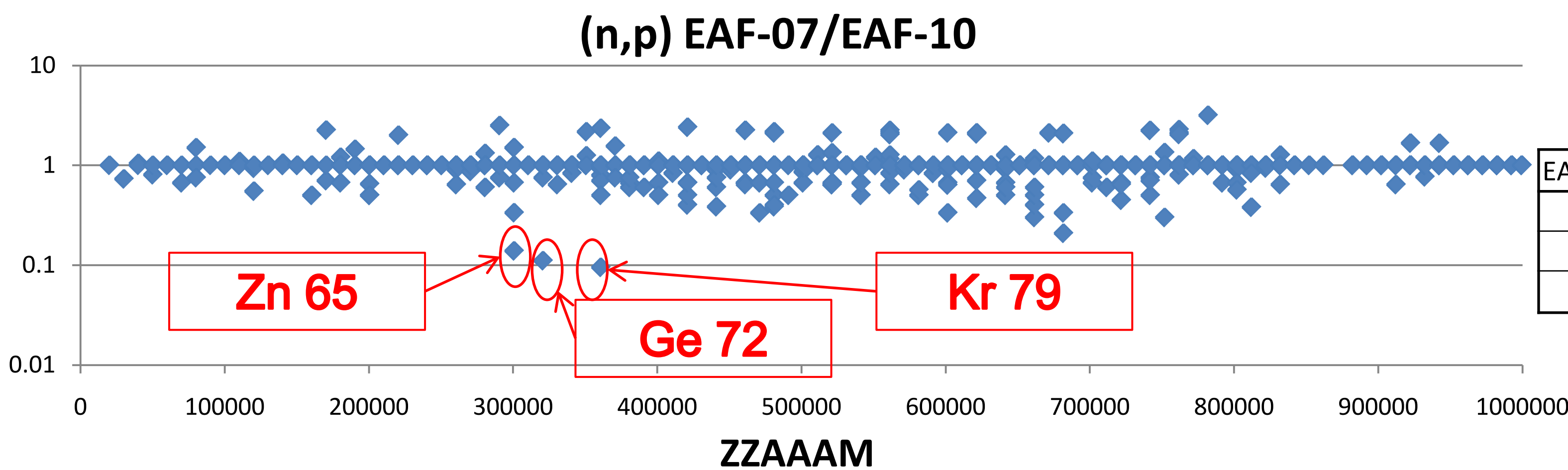


EAF-07/EAF-10	Statistics (%)
f=1	37.25
f<1	12.75
f>1	50.00

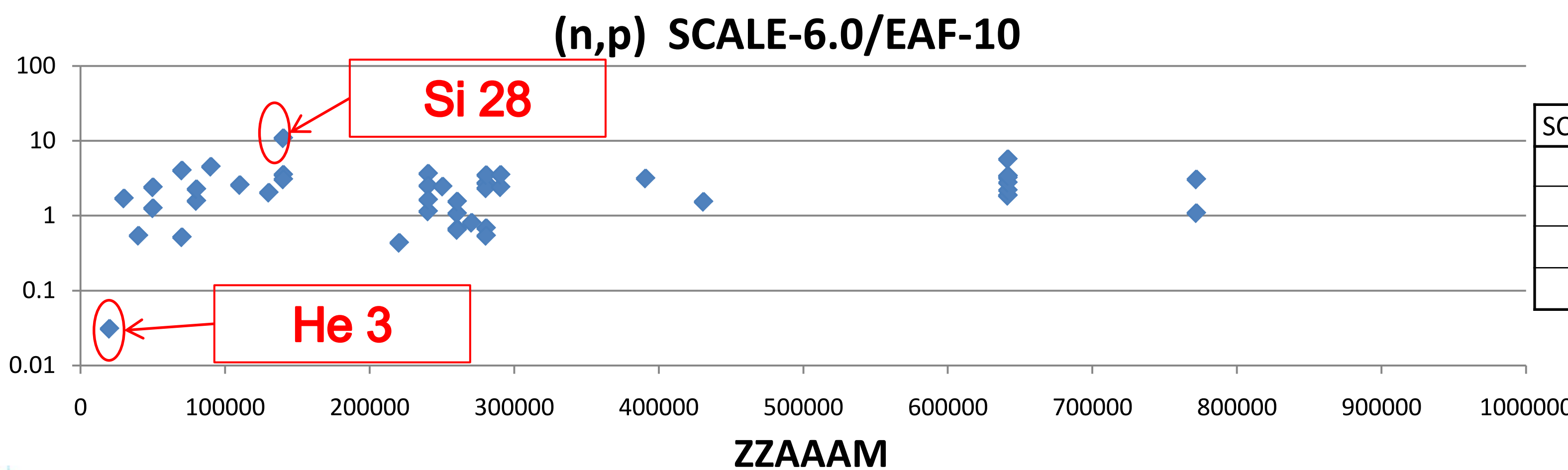


SCALE/EAF-10	Statistics (%)
f=1	0.00
f=0	42.16
0<f<1	38.24
f>1	19.61

ADS Uncertainty collapsed in one energy group



EAF-07/EAF-10	Statistics (%)
f=1	77.33
f<1	15.69
f>1	6.97



SCALE/EAF-10	Statistics (%)
f=1	0.00
f=0	94.40
0<f<1	1.12
f>1	4.48

PWR Uncertainty Requirements

Table. **Critical cross-section uncertainties processed from BOLNA covariance matrices and their target accuracies**

System studied:

Extended BU PWR
- U-235 enrichment: 8.5%
- Burnup 100 GW d/kg.

Table 22. PWR target accuracies (1σ)

k_{eff}	Doppler reactivity coefficient	Burn-up $\Delta\rho$	Transmutation
0.5%	10%	500 pcm	5%

- **List of priorities**

➢ Fission cross sections (n,f): ^{239}Pu, ^{241}Pu

➢ Capture cross sections (n, γ): ^{235}U, ^{238}U, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{16}O

Table 8. PWR target accuracy results

Isotope	Cross-section	Energy range	Uncertainty (%) Initial	Required λ=1	Required λ≠1 [a]
^{235}U	σ_{capt}	67.4-24.8 keV	32.9	19.9	18.5
		24.8-9.12 keV	34.0	17.8	16.2
		9.12-2.03 keV	33.9	11.5	10.3
^{238}U	σ_{capt}	24.8-9.12 keV	9.4	4.6	4.0
		9.12-2.03 keV	3.1	3.1	2.9
		454-22.6 eV	1.7	1.4	1.3
	σ_{scatt}	19.6-6.07 MeV	13.3	13.1	11.6
		6.07-2.23 MeV	14.6	5.1	4.6
		2.23-1.35 MeV	18.8	8.0	7.1
^{239}Pu	σ_{capt}	0.54-0.10 eV	1.4	1.0	0.9
	σ_{fiss}	0.54-0.10 eV	0.9	0.9	0.8
^{240}Pu	σ_{capt}	0.54-0.10 eV	3.2	3.1	3.2
		0.10 eV-thermal	4.8	3.1	4.0
^{241}Pu	σ_{capt}	22.6-4.00 eV	8.4	7.3	8.4
		0.54-0.10 eV	6.8	3.0	3.8
	σ_{fiss}	2.03-0.454 keV	12.7	11.2	12.7
		454-22.6 eV	19.4	4.7	5.9
		22.6-4.00 eV	4.2	3.3	4.2
		4.00-0.54 eV	26.8	7.7	9.8
		0.54-0.10 eV	2.9	1.7	2.2
		0.10 eV-thermal	3.3	1.9	2.4
^{242}Pu	σ_{capt}	4.00-0.54 eV	3.8	3.4	3.8
O	σ_{capt}	19.6-6.07 MeV	100.0	12.1	10.9
		6.07-2.23 MeV	100.0	9.9	8.9
	σ_{scatt}	19.6-6.07 MeV	84.6	15.6	13.9
		6.07-2.23 MeV	54.9	12.6	11.3
		2.23-1.35 MeV	12.2	8.3	7.5

PWR Uncertainty Requirements: EAF2007-EAF2010

Using BOLNA covariance matrices

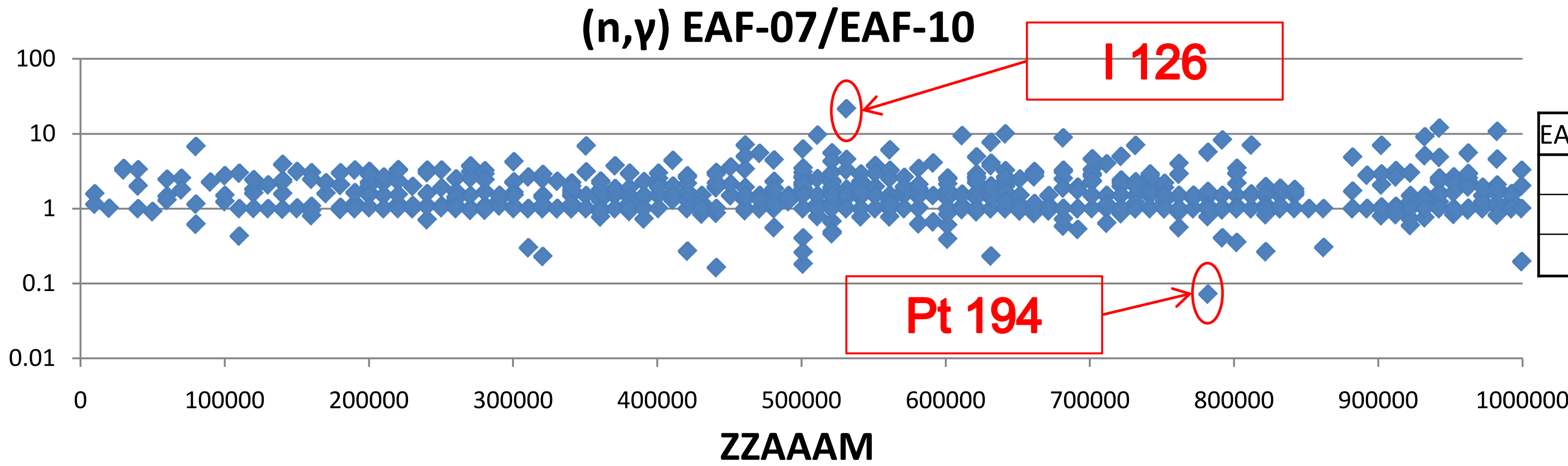
Isotpe		Cross-section	Energy range	Uncertainty			EAF - 2007		EAF - 2010	
				Initial	Required					
					λ=1	λ≠1	Energy Range	Uncertainty	Energy Range	Uncertainty
U	235	(n,γ)	67.4 - 24.8 keV	32.9	19.9	18.5	2.25 keV - 20 MeV	16.67	0.10 eV - 0.10 MeV	3.33
			24.8 - 9.12 keV	43	17.8	16.2				
			9.12 - 2.03 keV	33.9	11.5	10.3				
	238	(n,γ)	24.8 - 9.12 keV	9.4	4.6	4	10 keV - 20 MeV	16.67	0.5 eV - 0.10 MeV	3.33
			9.12 - 2.03 keV	3.1	3.1	2.9	1.0 eV - 10 keV	3.33		
			454 - 2.6 eV	1.7	1.4	1.3				
Pu	239	(n,γ)	0.54 - 0.10 eV	1.4	1	0.9	Thermal - 0.10 eV	3.70	0.10 eV - 0.10 MeV	4.27
		(n,fission)	0.54 - 0.10 eV	0.9	0.9	0.8	Thermal - 30 keV	3.33	Thermal - 0.50 eV	3.33
	240	(n,γ)	0.54 - 0.10 eV	3.2	3.1	3.2	0.10 eV - 4.0 keV	3.57	0.10 eV - 0.10 MeV	3.33
			0.10 eV - thermal	4.8	3.1	4	Thermal - 0.10 eV	3.43	Thermal - 0.10 eV	3.33
	241	(n,γ)	22.6 - 4.00 eV	8.4	7.3	8.4	0.10 eV - 0.30 keV	6.27	0.10 eV - 0.10 MeV	3.33
			0.54 - 0.10 eV	6.8	3	3.8				
		(n,fission)	2.03 - 0.454 keV	12.7	11.2	12.7	Thermal - 30 keV	3.33	Thermal - 0.10 MeV	3.33
			454 - 22.6 eV	19.4	4.7	5.9				
			22.6 - 4.00 eV	4.2	3.3	4.2				
			4.00 - 0.54 eV	26.8	7.7	9.8				
			0.54 - 0.10 eV	2.9	1.7	2.2				
			0.10 eV - thermal	3.3	1.9	2.4				
	242	(n,γ)	4.00 - 0.54 eV	3.8	3.4	3.8	0.05 eV - 1.29 keV	9.10	0.50 eV - 0.10 MeV	3.33
O		(n,γ)	19.6 - 6.07 MeV	100	12.1	10.9	1.0 MeV - 20 MeV	33.33	1.0 MeV - 20 MeV	33.33
			6.07 - 2.23 MeV	100	9.9	8.9				

PWR Uncertainty collapsed in one energy group

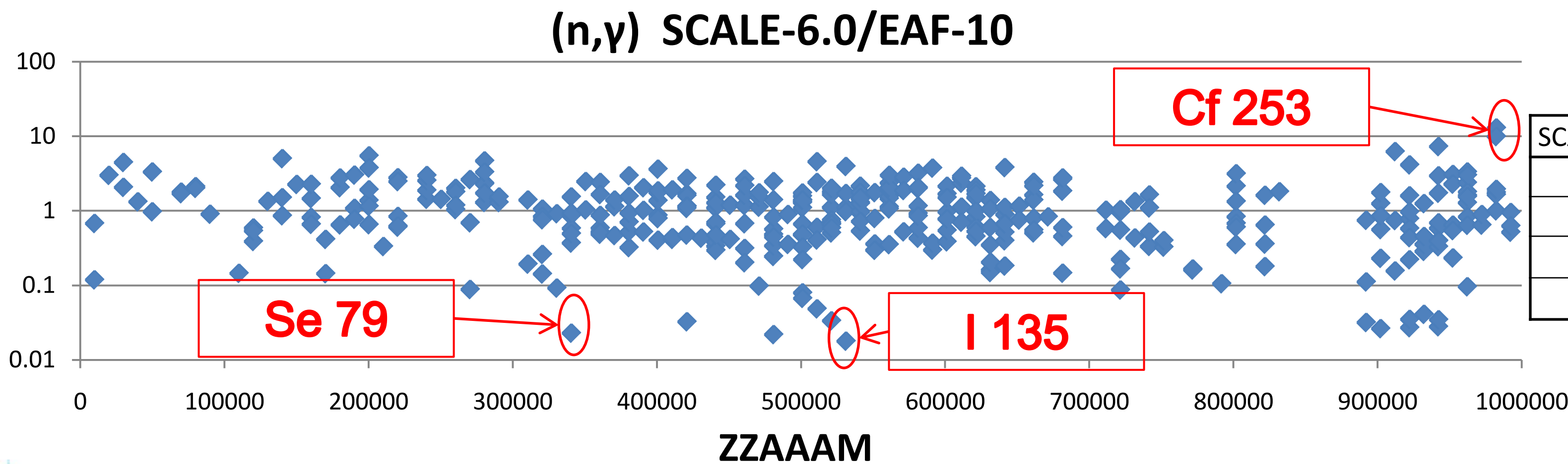
To compare values	Best	Regular	Worst

ISOTOPE		(n,fission) EAF-2007	(n,fission) EAF-2010	(n,fission) SCALE 6.0	(n,γ) EAF-2007	(n,γ) EAF-2010	(n,γ) SCALE 6.0	(n,γ-M) EAF-2007	(n,γ-M) EAF-2010	(n,γ-M) SCALE 6.0
U	234	15.86	15.84	24.82	38.87	26.03	5.73	38.87	26.03	
	235	2.39	2.39	0.33	2.64	2.35	1.35			
	236	11.67	12.16	19.5	3.85	3.1	2.99			
	238	16.65	16.65	0.52	3.15	3.17	1.38			
Np	237	16.5	16.41	7	5.72	7.58	2.68			
Pu	238	7.23	4.86	6.01	3.73	3.07	1.79			
	239	3.32	3.2	0.78	8.21	3.55	1.17			
	240	14.94	14.27	2.7	3.3	3.09	1.23			
	241	3.3	3.32	0.87	3.9	2.39	0.94			
	242	15.81	15.77	4.53	8.51	3.31	9.76			
	244	16.56	16.56	21.32	23.48	4.87	35.39			
Am	241	21.34	12.44	1.66	6.38	3.89	2.5	8.08	9.21	
	241M	3.31	3.33	3.05	22.36	10.19	23.2			
	243	15	14.62	5.12	3.72	4.44	2.41	8	3.04	
Cm	242	16.6	10.79	32.83	19.29	9.42	12.05			
	243	3.94	2.56	2.71	5.94	2.35	5.58			
	244	13.36	12.22	25.8	6.93	3.01	9.99			
	245	3.65	5.03	2.45	14.68	2.67	4.28			
	246	14.6	13.67	8.37	7.99	3.15	5.63			
	247	4.96	5.25	13.04	16.51	7.63	6.33			
	248	12.91	13.36	16.33	10.48	3.57	5.5			
Bk	249	28.84	14.56	6.47	9.52	7.74	4.96			
Cf	249	7.3	2.6	1.76	3.94	2.51	4.39			
	250	13.81	41.36	0.6	4.85	5.93	5.91			
	251	8.74	5.7	4.37	5.95	2.88	4.73			
	252	11.69	4.84	11.5	12.14	2.65	5.13			

PWR Uncertainty collapsed in one energy group

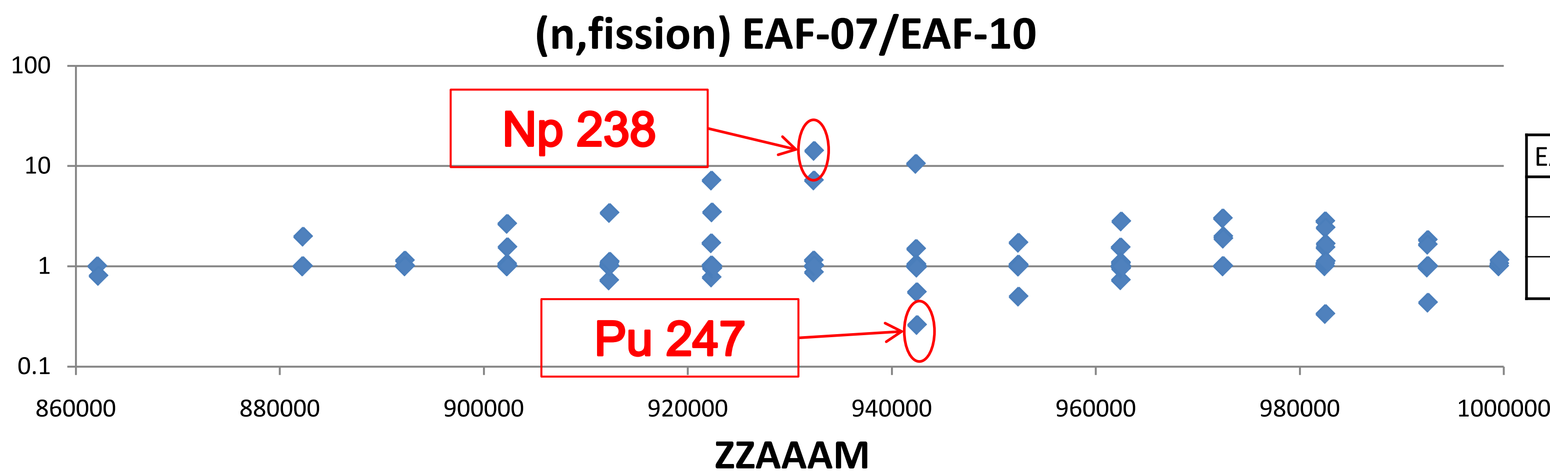


EAF-07/EAF-10	Statistics (%)
f=1	24.14
f<1	10.71
f>1	65.15

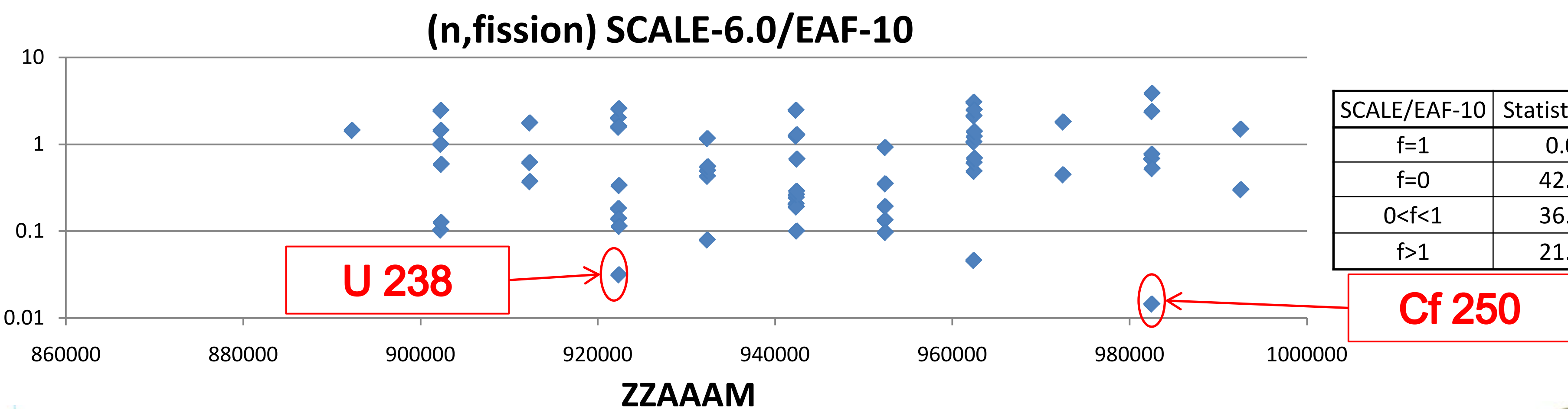


SCALE/EAF-10	Statistics (%)
f=1	0.00
f=0	53.69
0<f<1	24.51
f>1	21.80

PWR Uncertainty collapsed in one energy group

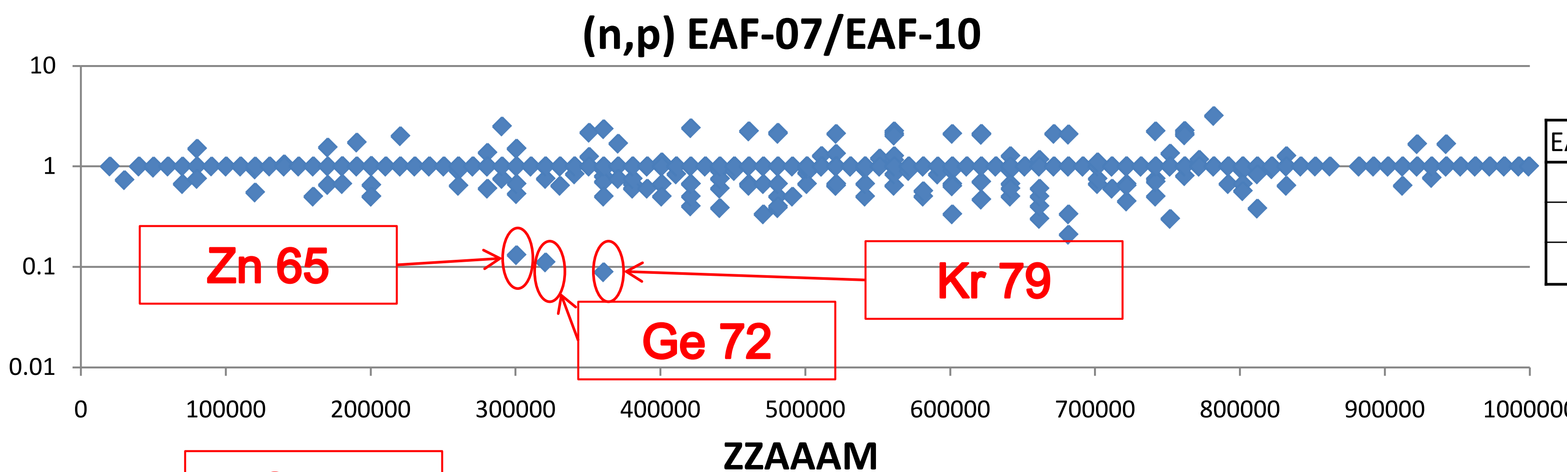


EAF-07/EAF-10	Statistics (%)
f=1	23.53
f<1	21.57
f>1	54.90

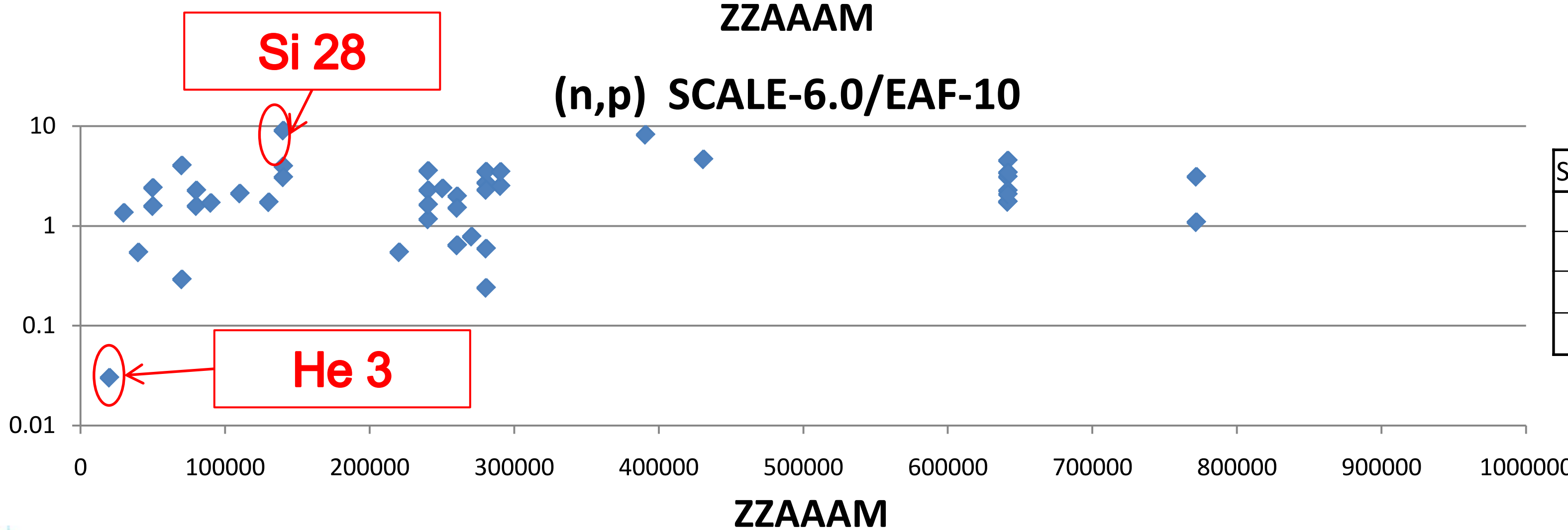


SCALE/EAF-10	Statistics (%)
f=1	0.00
f=0	42.16
0<f<1	36.27
f>1	21.57

PWR Uncertainty collapsed in one energy group



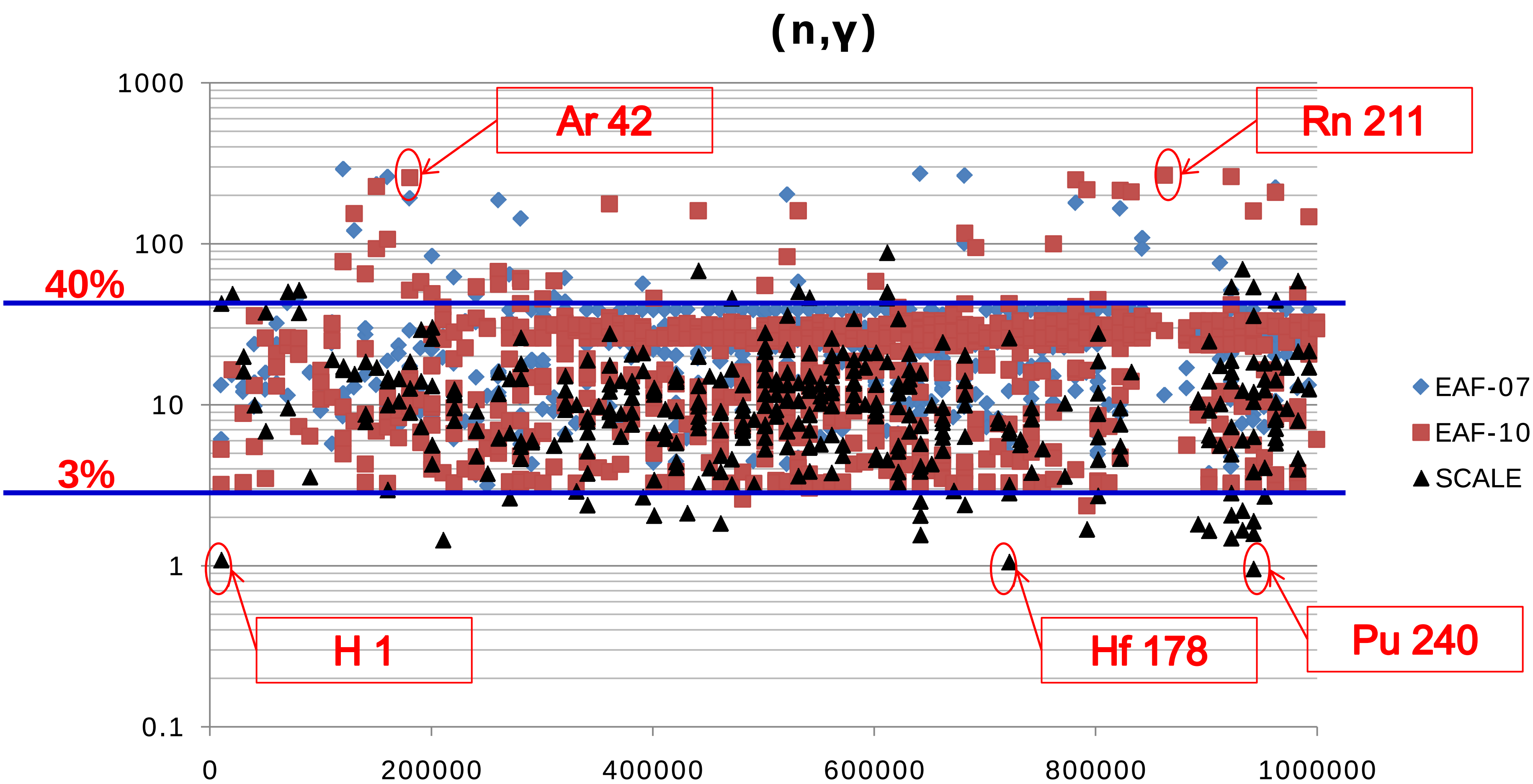
EAF-07/EAF-10	Statistics (%)
f=1	78.95
f<1	14.32
f>1	6.72



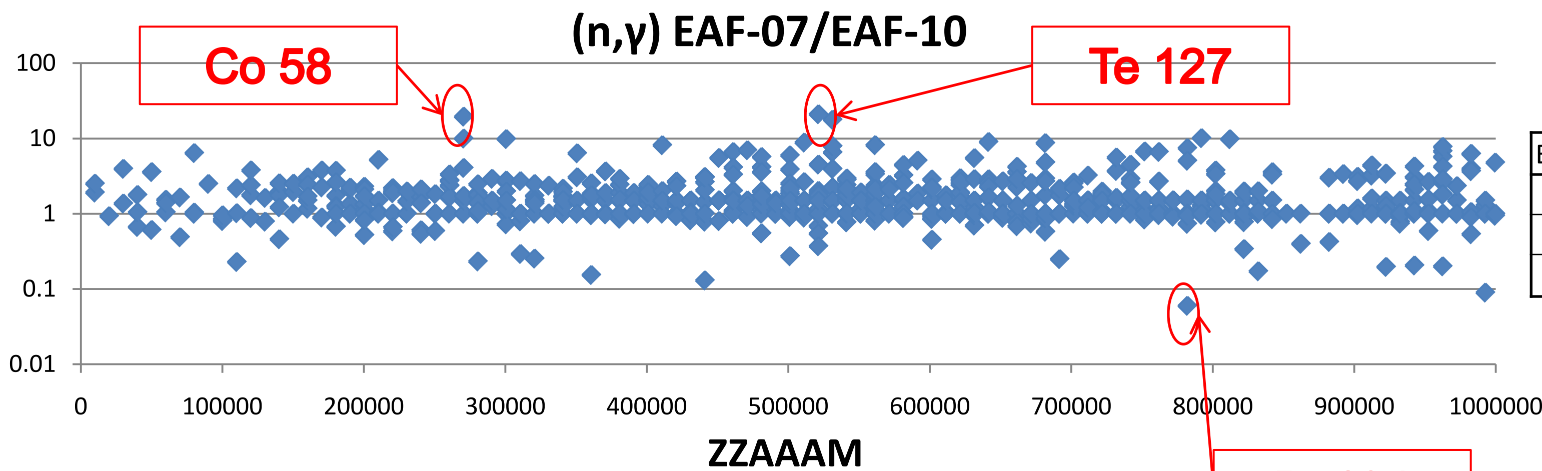
SCALE/EAF-10	Statistics (%)
f=1	0.00
f=0	94.40
0<f<1	1.12
f>1	4.48

FUSION application: DEMO

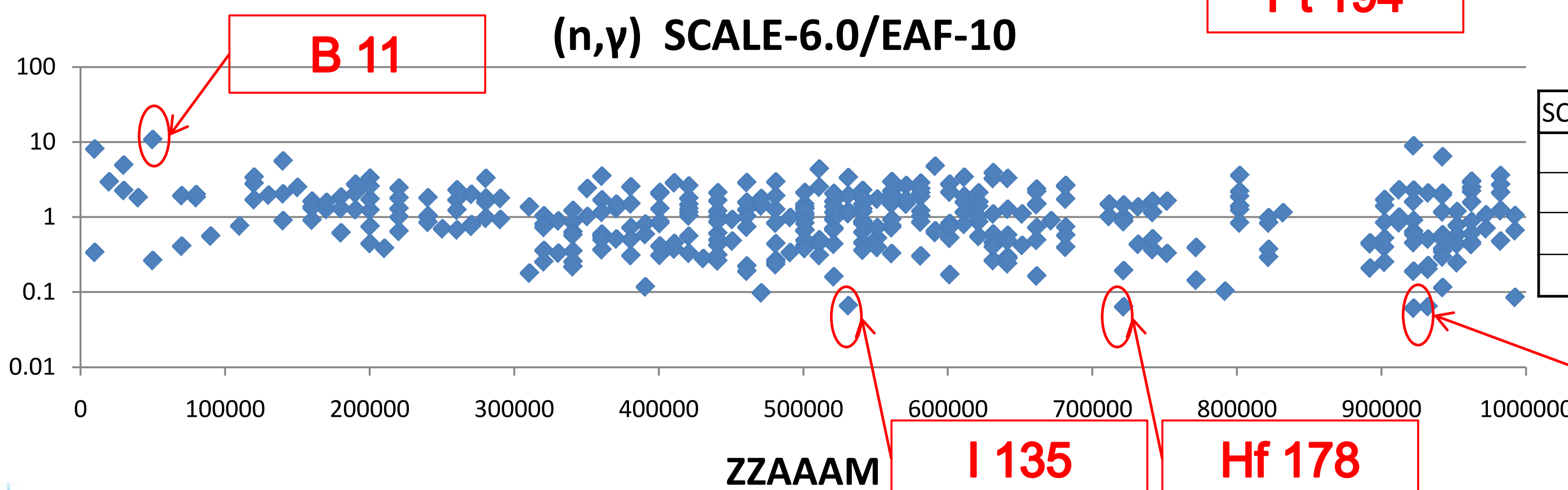
Cross-section uncertainties collapsed in one-group using DEMO neutron spectrum



Cross-section uncertainties collapsed in one-group using DEMO neutron spectrum



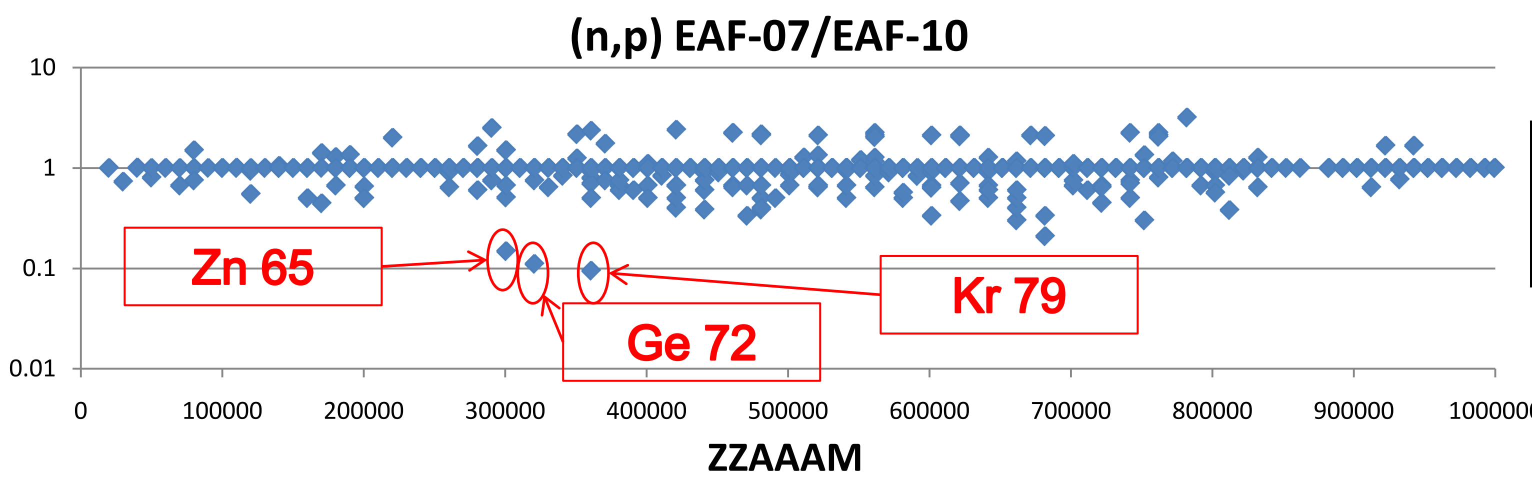
EAF-07/EAF-10	Statistics (%)
f=1	26.11
f<1	12.44
f>1	61.45



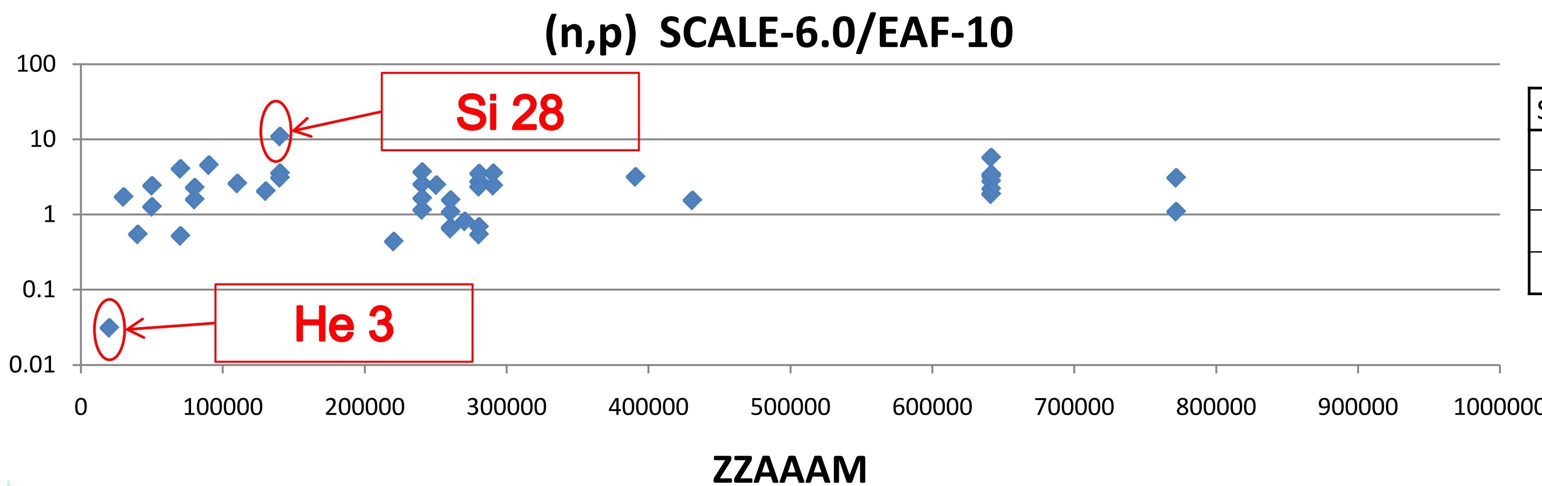
SCALE/EAF-10	Statistics (%)
f=1	0.00
f=0	53.69
0<f<1	23.77
f>1	22.54

FUSION application: DEMO

Cross-section uncertainties collapsed in one-group using DEMO neutron spectrum

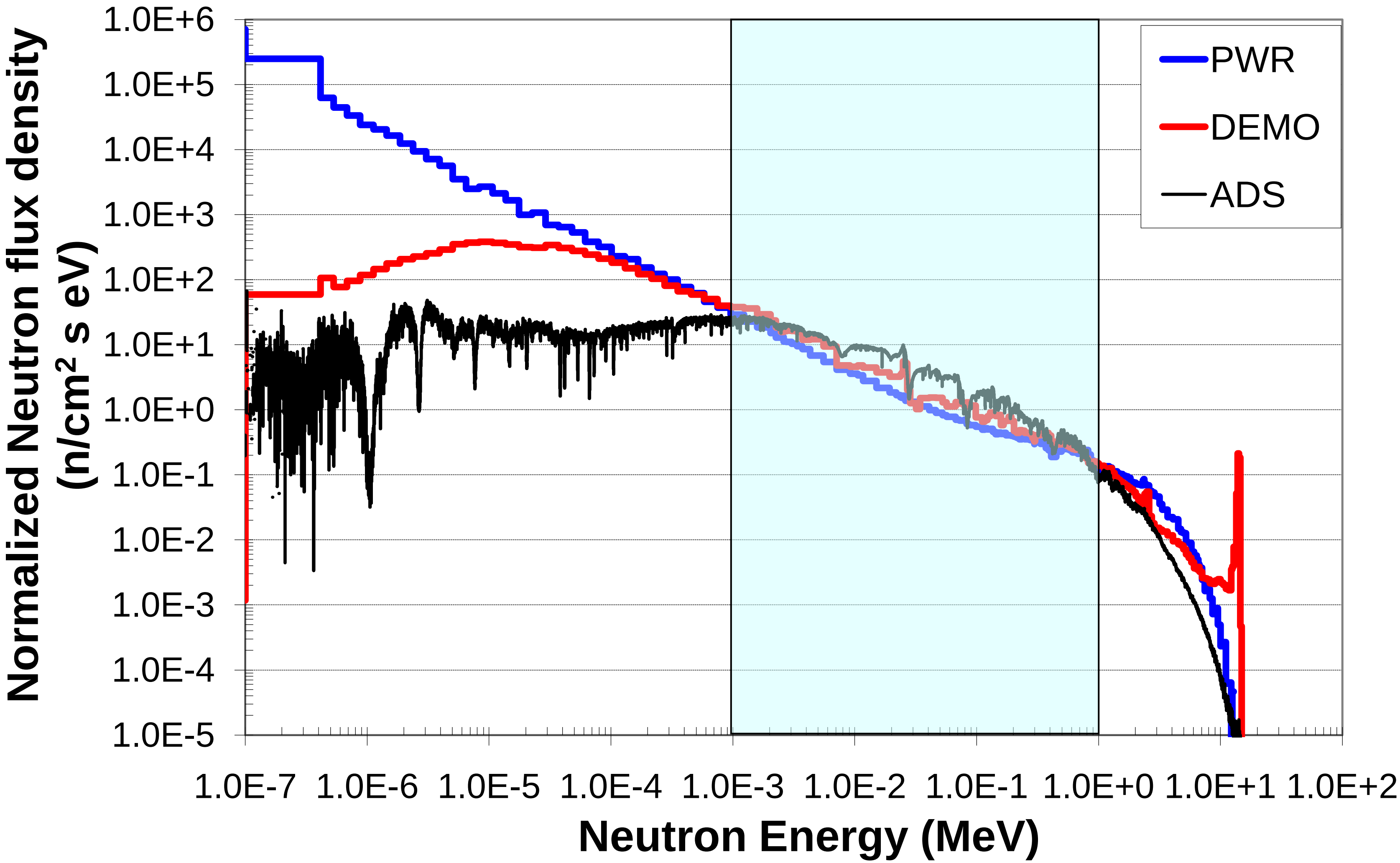


EAF-07/EAF-10	Statistics (%)
f=1	79.08
f<1	14.45
f>1	6.48



SCALE/EAF-10	Statistics (%)
f=1	0.00
f=0	94.40
0<f<1	1.12
f>1	4.48

Neutron spectrum effect



Neutron spectrum effect: (n,gamma)

To compare values: Best | Regular | Worst

(n,γ)		EAF-2007			EAF-2010			SCALE 6.0		
ISOTOPE		PWR	ADS	DEMO	PWR	ADS	DEMO	PWR	ADS	DEMO
U	234	38.87	38.87	38.87	26.03	26.03	26.03	5.73	6.93	4.95
	235	2.64	11.28	4.75	2.35	3.23	3.2	1.35	21.8	7.32
	236	3.85	8.9	4.11	3.1	3.2	3.24	2.99	3.11	2.07
	238	3.15	6.67	3.27	3.17	3.17	3.27	1.38	1.44	1.49
Np	237	5.72	14.33	7.63	7.58	9.13	9.79	2.68	3.3	2.21
Pu	238	3.73	14.46	9.99	3.07	3.69	3.27	1.79	6.63	3.84
	239	8.21	12.48	8.64	3.55	4.21	4.18	1.17	4.86	1.59
	240	3.3	9.26	3.52	3.09	3.62	3.28	1.23	1.2	0.96
	241	3.9	15.37	7.99	2.39	5.22	3.27	0.94	4	1.9
	242	8.51	12.62	8.01	3.31	3.51	3.27	9.76	5	6.36
	244	23.48	30.44	23.86	4.87	7.36	5.64	35.39	24.88	35.87
Am	241	6.38	15.81	9.72	3.89	16.65	16.55	2.5	4.67	4.08
	241M	22.36	32.77	27.78	10.19	13.18	10.48	23.2	14.66	12.4
	243	3.72	15.34	7.28	4.44	4.98	4.71	2.41	4.48	2.71
Cm	242	19.29	30.01	24.25	9.42	12.86	13.65	12.05	10.8	6.25
	243	5.94	31.97	20.18	2.35	5.21	3.56	5.58	14.24	10.39
	244	6.93	24.56	8.47	3.01	3.72	3.27	9.99	7.72	7.18
	245	14.68	32.75	25.83	2.67	4.13	3.35	4.28	9.83	8.35
	246	7.99	28.21	13.82	3.15	3.7	3.29	5.63	20.32	8.11
	247	16.51	32.12	23.03	7.63	7.67	8.17	6.33	20.59	7.13
	248	10.48	19.19	10.57	3.57	3.79	3.68	5.5	16.85	5.79
Bk	249	9.52	31.73	20.56	7.74	8.82	8.86	4.96	23.99	9.49
Cf	249	3.94	32.39	23.13	2.51	4.8	3.73	4.39	24.59	13.35
	250	4.85	29.33	8.72	5.93	8.97	9.72	5.91	16.06	4.65
	251	5.95	29.95	12.72	2.88	3.85	3.22	4.73	16.89	3.99
	252	12.14	31.22	23.64	2.65	4.03	3.8	5.13	18.11	8.01

Neutron spectrum effect: (n,fission)

To compare values: Best | Regular | Worst

(n,fission)		EAF-2007			EAF-2010			SCALE 6.0		
ISOTOPE		*PWR*	*ADS*	*DEMO*	*PWR*	*ADS*	*DEMO*	*PWR*	*ADS*	*DEMO*
U	234	15.86	16.47	16.43	15.84	16.47	16.43	24.82	29.99	15.37
	235	2.39	12.86	6.99	2.39	5.5	4.7	0.33	0.41	0.3
	236	11.67	15.88	15.68	12.16	15.31	15.63	19.5	27.16	11.42
	238	16.65	16.61	16.66	16.65	16.61	16.66	0.52	0.54	0.55
Np	237	16.5	16.66	16.64	16.41	16.39	16.55	7	6.55	3.81
Pu	238	7.23	12.35	12.5	4.86	10.09	11.21	6.01	10.55	10.75
	239	3.32	9.59	6.02	3.2	7.87	6.48	0.78	0.4	0.58
	240	14.94	15.84	16.16	14.27	14.68	15.87	2.7	0.57	0.59
	241	3.3	15.58	8.79	3.32	5.64	4.3	0.87	1.23	0.75
	242	15.81	16.46	16.52	15.77	16.46	16.52	4.53	3.43	3.61
	244	16.56	16.48	16.6	16.56	16.47	16.59	21.32	18.96	17.29
Am	241	21.34	16.62	16.4	12.44	16.62	16.4	1.66	2.19	2.71
	241M	3.31	16.48	15.1	3.33	5.59	4.28	3.05	9.88	7.28
	243	15	16.61	16.48	14.62	15.95	16.29	5.12	5.76	9.67
Cm	242	16.6	16.52	16.17	10.79	16.51	15.66	32.83	31.85	24.37
	243	3.94	16	10.64	2.56	5.91	4.68	2.71	19.72	9.03
	244	13.36	16.42	15.93	12.22	14.82	15.39	25.8	37.01	21.33
	245	3.65	9.75	7.3	5.03	11.33	12.56	2.45	20.18	9.45
	246	14.6	16.59	16.41	13.67	15.24	15.99	8.37	8.01	8.58
	247	4.96	16.46	14.43	5.25	16.46	14.44	13.04	11.3	11.42
	248	12.91	16.19	15.41	13.36	15.28	15.33	16.33	16.17	16.11
Bk	249	28.84	16.61	16.44	14.56	16.61	16.44	6.47	22.5	20.02
Cf	249	7.3	16.28	12.85	2.6	5.83	4.79	1.76	19.35	7.31
	250	13.81	32.97	29.36	41.36	32.98	30.73	0.6	13.32	12.85
	251	8.74	31.57	17.82	5.7	12.92	9.5	4.37	22.02	9.23
	252	11.69	14.95	14.72	4.84	10.68	9.74	11.5	6.11	12.54

SUMMARY & CONCLUSIONS of PART I

- **ADS**
  - EAF2010 shows a real improvement
    - →**To be used as a "reference" activation uncertainty library**
  - SCALE6.0 should be used as a "reference" uncertainty library
    - → **Fulfil most accuracy requirements**
- **PWR**
  - EAF2010 shows an improvement, but does not fulfil all target accuracies
  - SCALE6.0 lacks in giving uncertainties for all isotopes
    - → Obtains the **lowest uncertainties** for **U, Np, Pu, Am, Cm, Bk, Cf** on **(n,f)**
    - → Obtains the **lowest uncertainties** for **U, Np, Pu** on **(n,g)**
- **DEMO**
  - The bulk of cross-section uncertainties is between 3% and 40% for most isotopes
  - EAF2010 reduces most of uncertainties, **but not for (n,p)**
  - SCALE6.0 uncertainties **do not reach lower errors than EAF-2010**, but **have some lowest values** for some isotopes

- **Neutron spectrum effect:**
  - ADS spectrum has the worst effect on one-group uncertainties
  - PWR spectrum reaches the lowest uncertainties
  - DEMO spectrum produces cross-section uncertainties between ADS and PWR because it is a mix of fast and thermal energies

Processing uncertainty libraries

Objectives:

1) Processing and testing **EAF2007/2010 and SCALE6.0** for activation calculations with NJOY

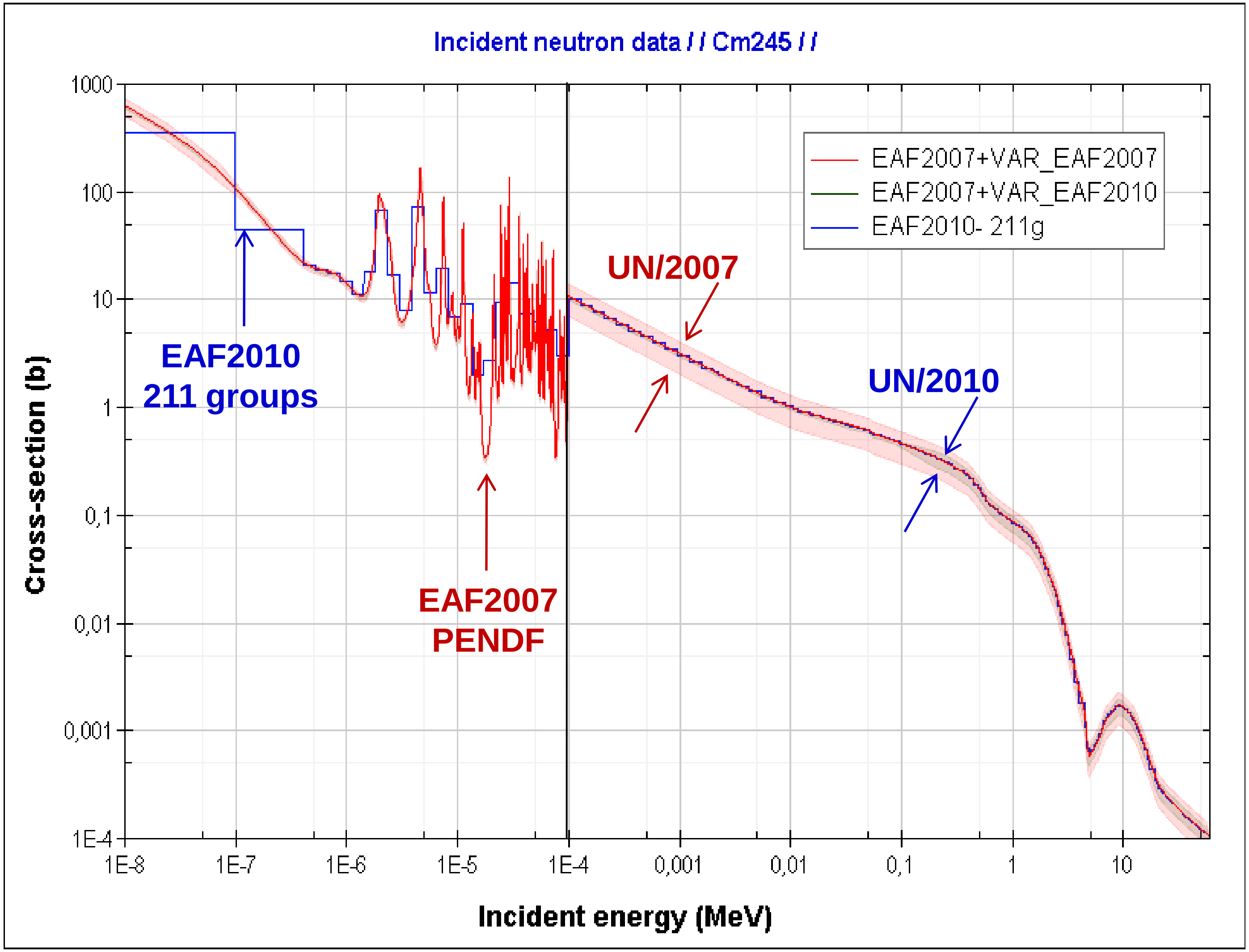
   - Processing EAF2007/2010 into ENDF6 format to use NJOY
   - Processing SCALE6.0 from coverx format (ANGELO/LAMBDA codes)

2) Processing and testing **TENDL2010/EAF** and **/ENDF** to activation calculations with NJOY

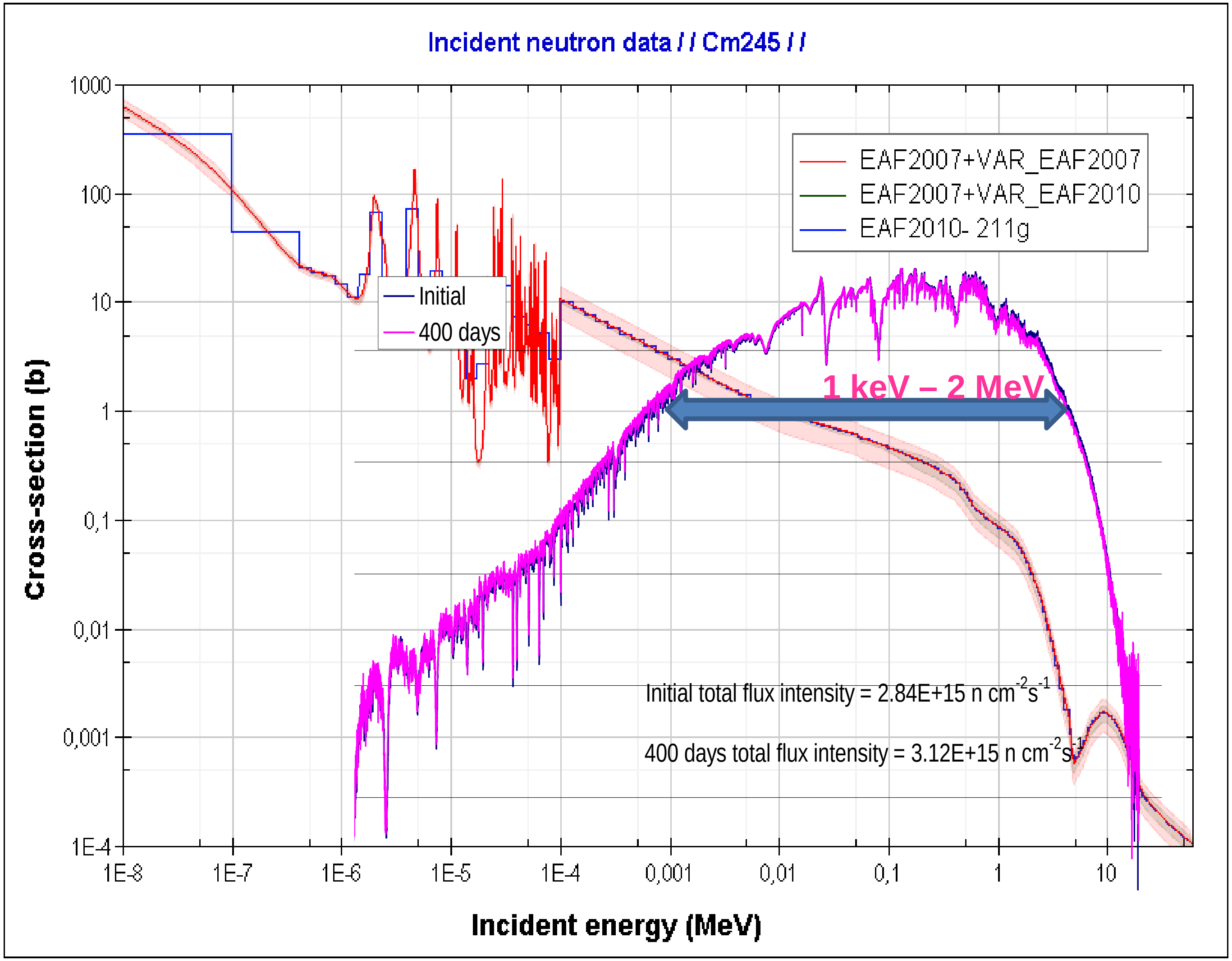
   - Processing EAF/TENDL2010 into ENDF format to use NJOY
   - Processing ENDF/TENDL2010

3) Applications: **^{245}Cm(n,γ) and ^{240}Pu(n,γ)**

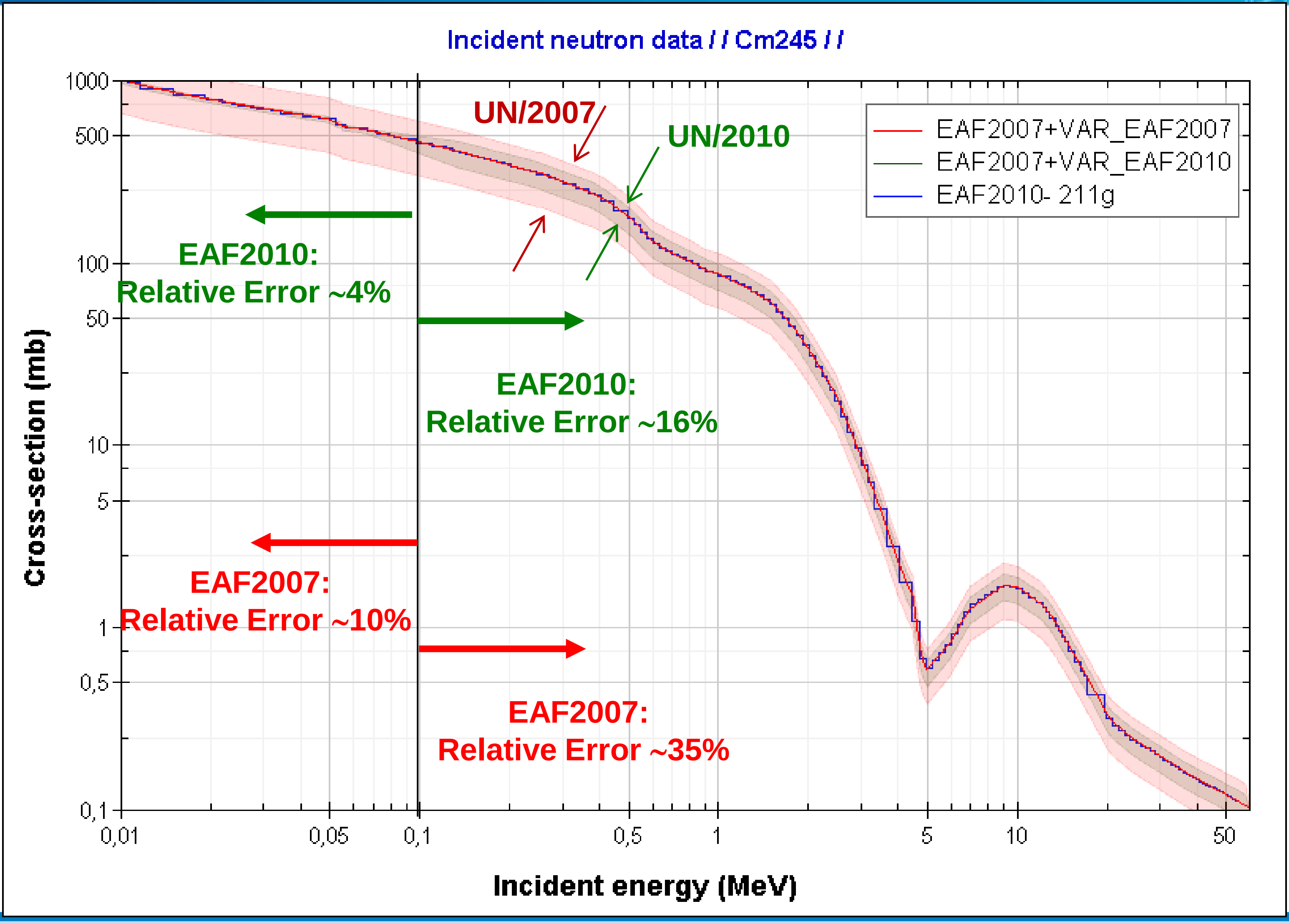
A comparison of EAF2007 & EAF2010: $^{245}Cm(n,\gamma)$



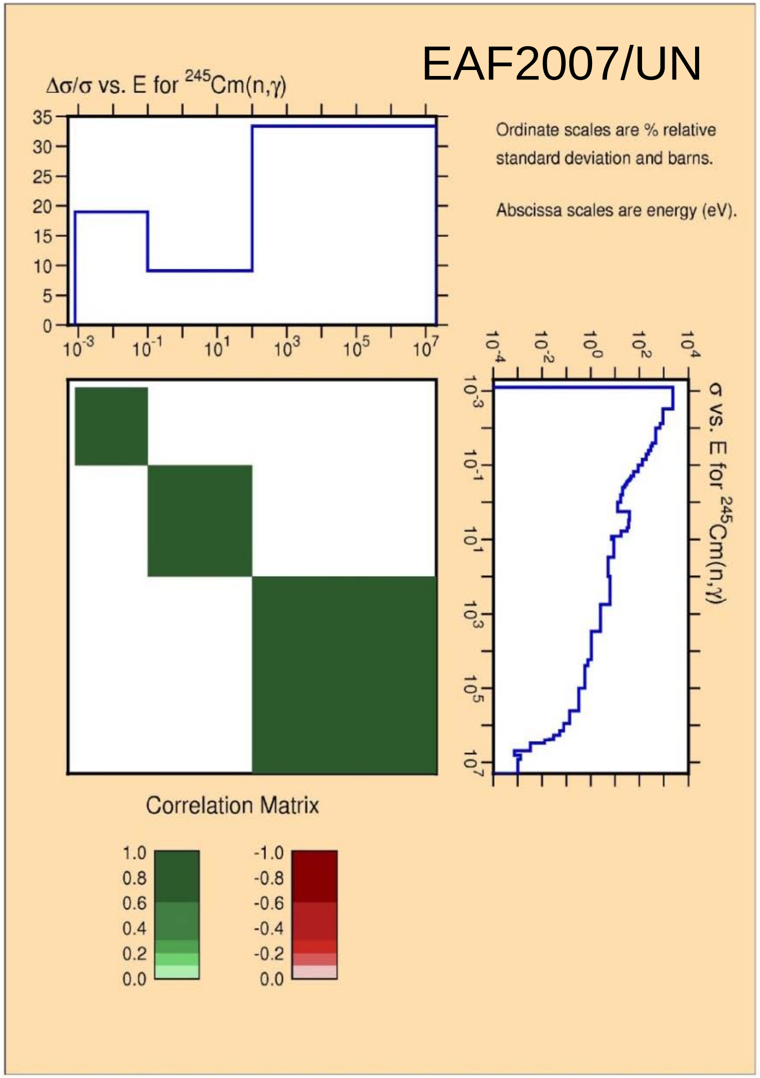
A comparison of EAF2007 & EAF2010: $^{245}Cm(n,\gamma)$

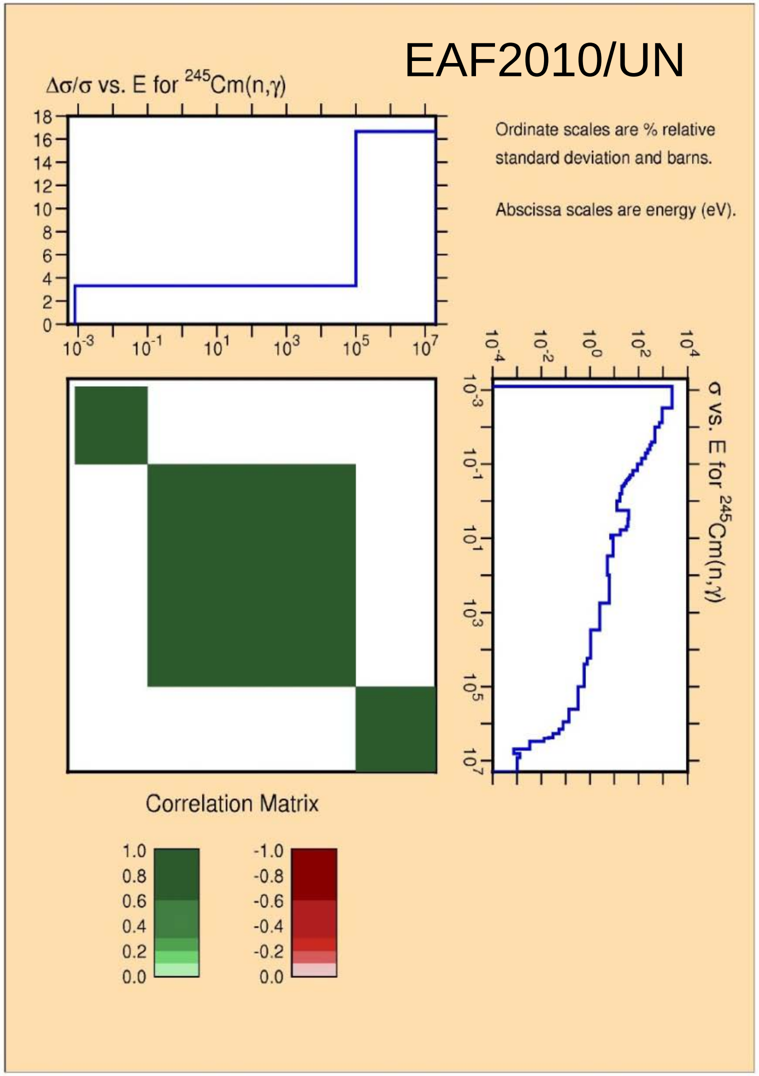


A comparison of EAF2007 & EAF2010: $^{245}Cm(n,\gamma)$

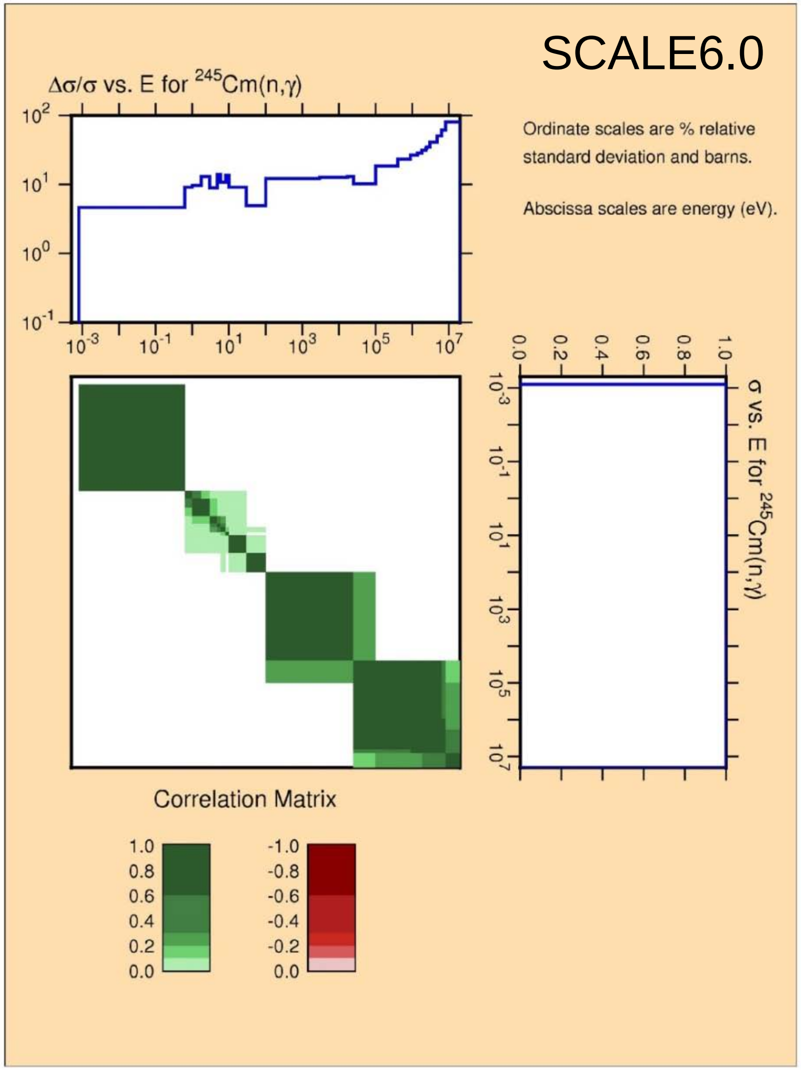


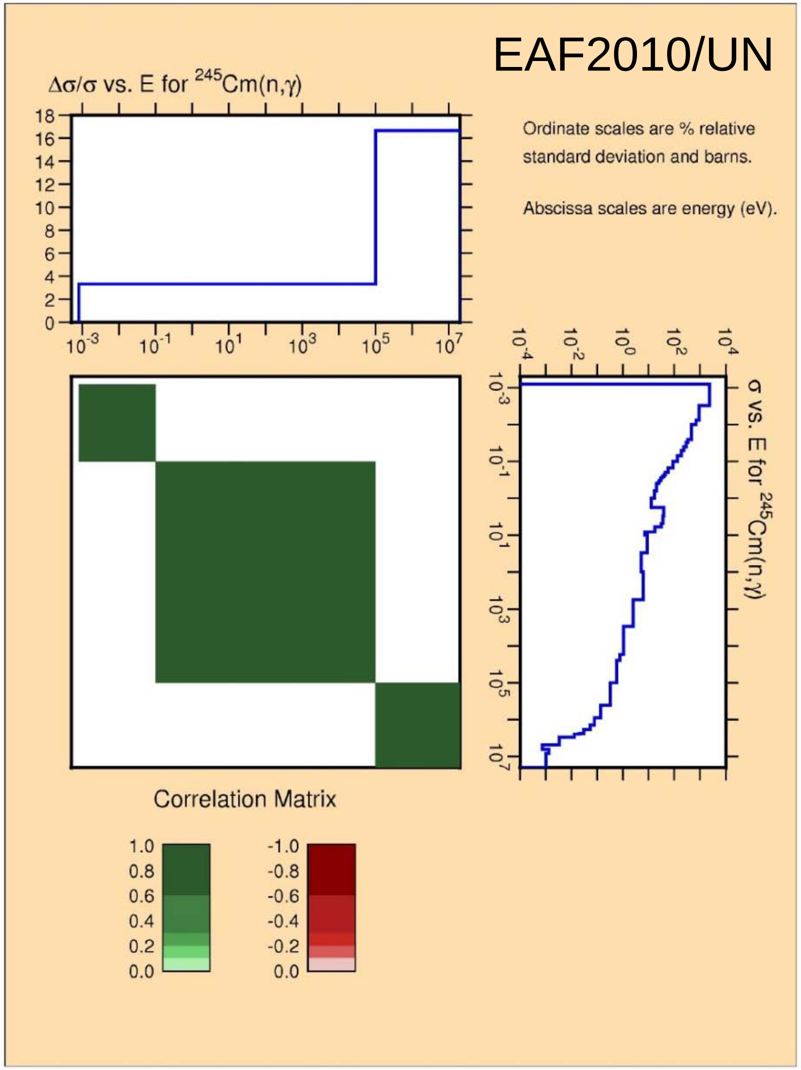
A comparison of EAF2007 & EAF2010: $^{245}Cm(n,\gamma)$



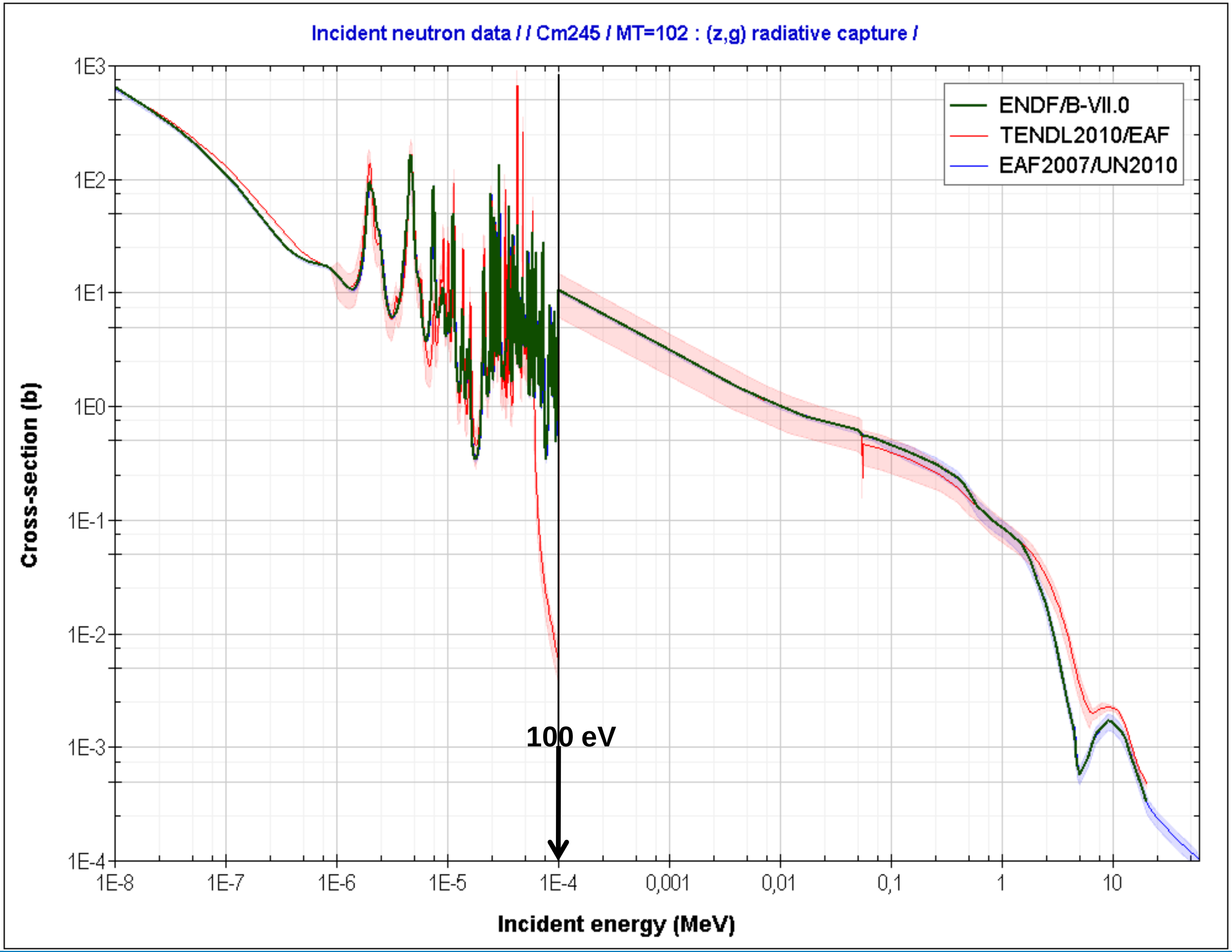


A comparison of EAF2010 & SCALE6.0: $^{245}Cm(n,\gamma)$

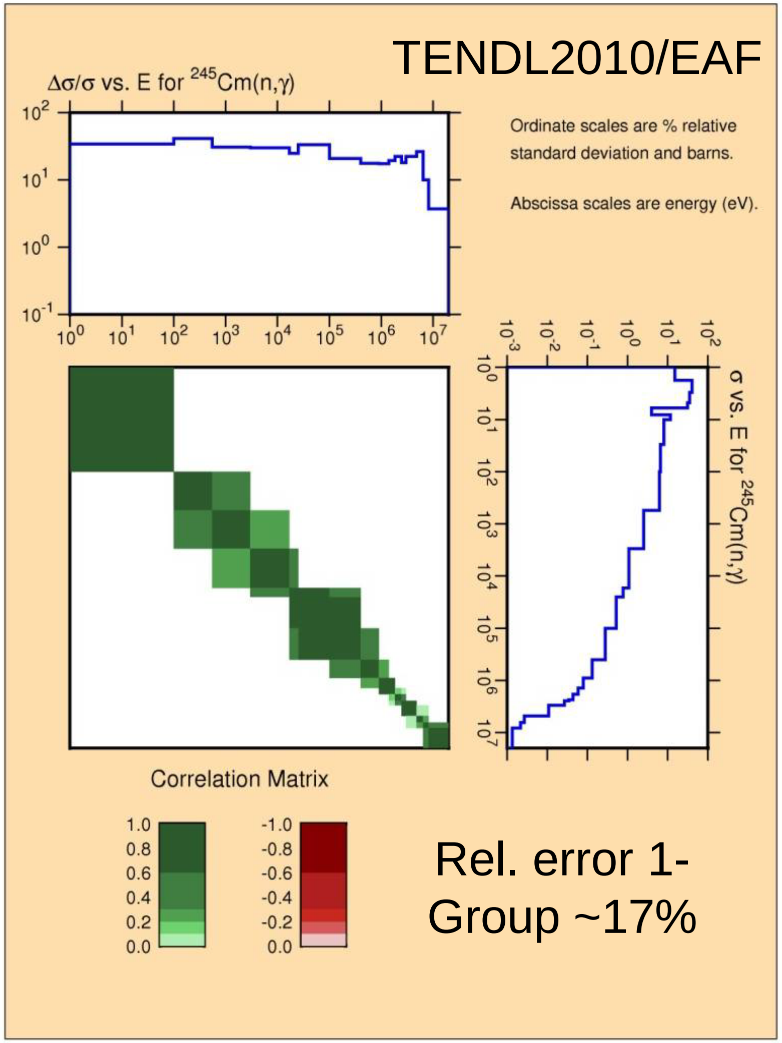


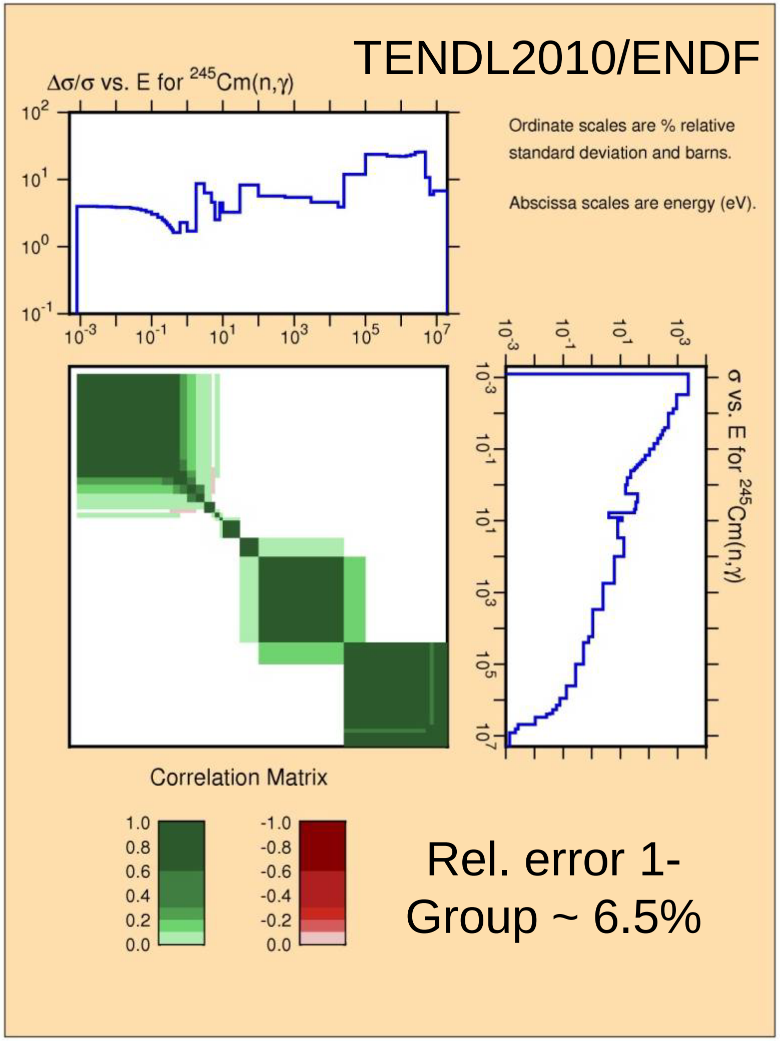


A comparison of EAF2007 & TENDL2010: $^{245}Cm(n,\gamma)$

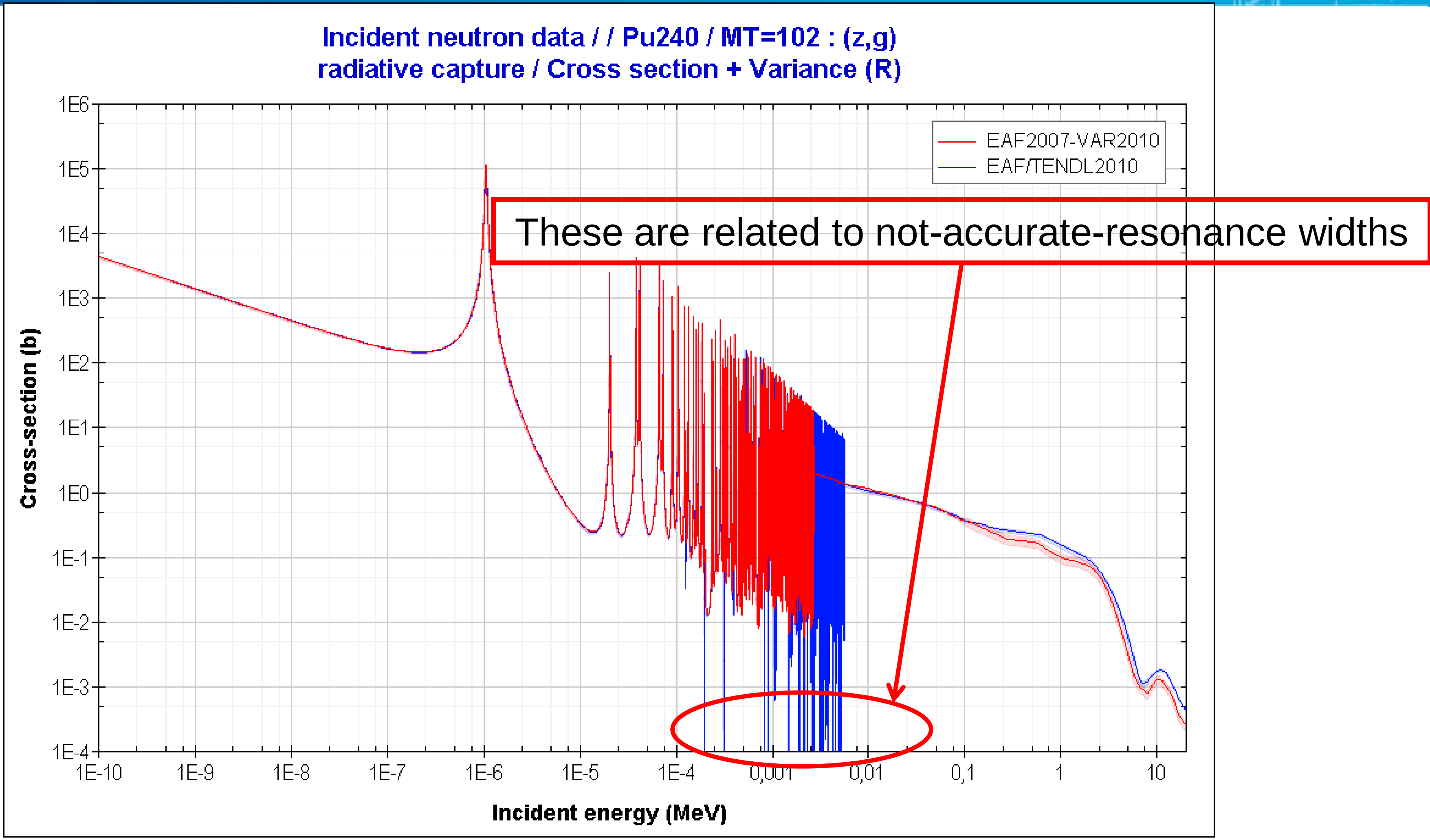


$^{245}Cm(n,\gamma)$ –TENDL2010, in EAF and ENDF formats

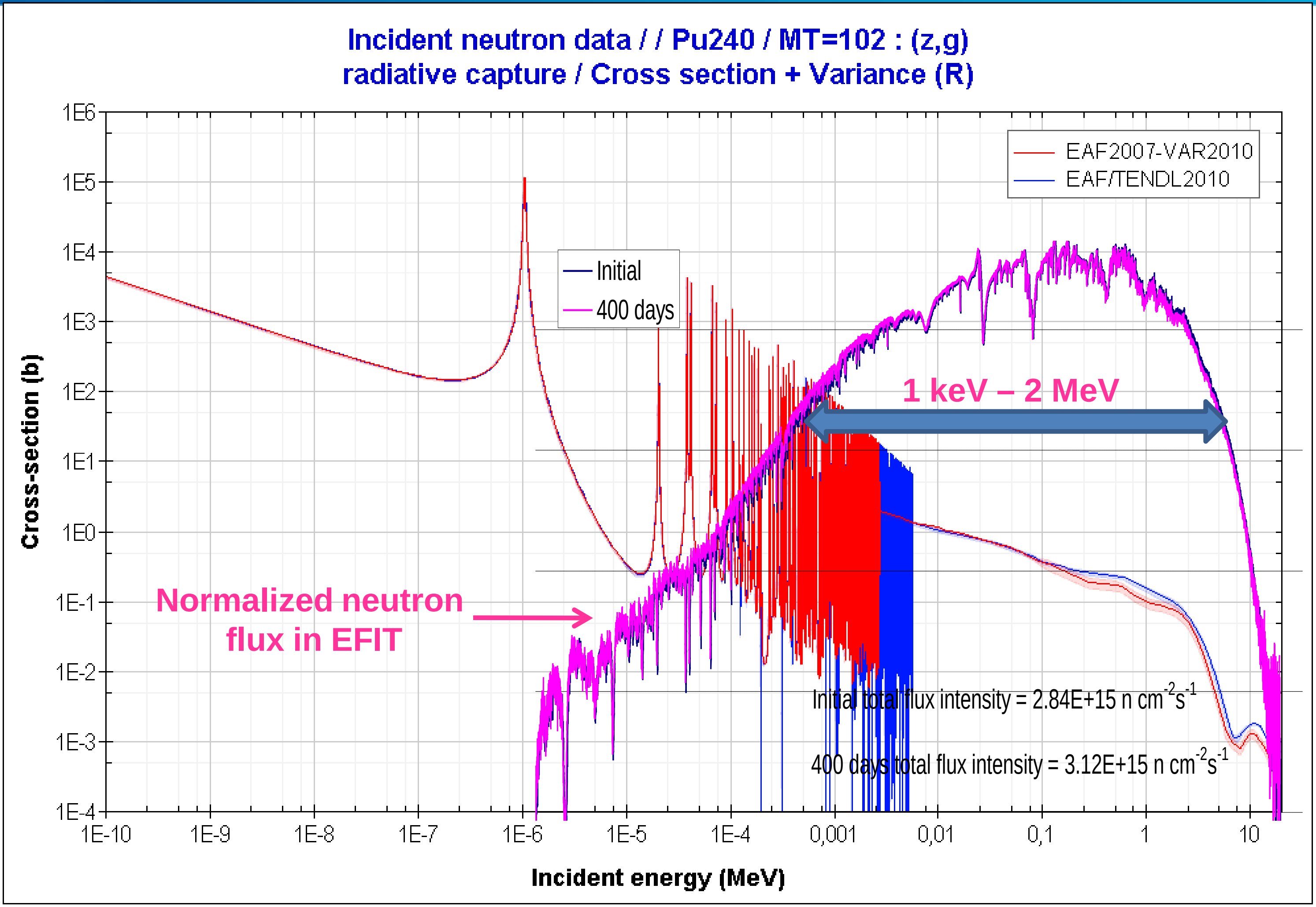




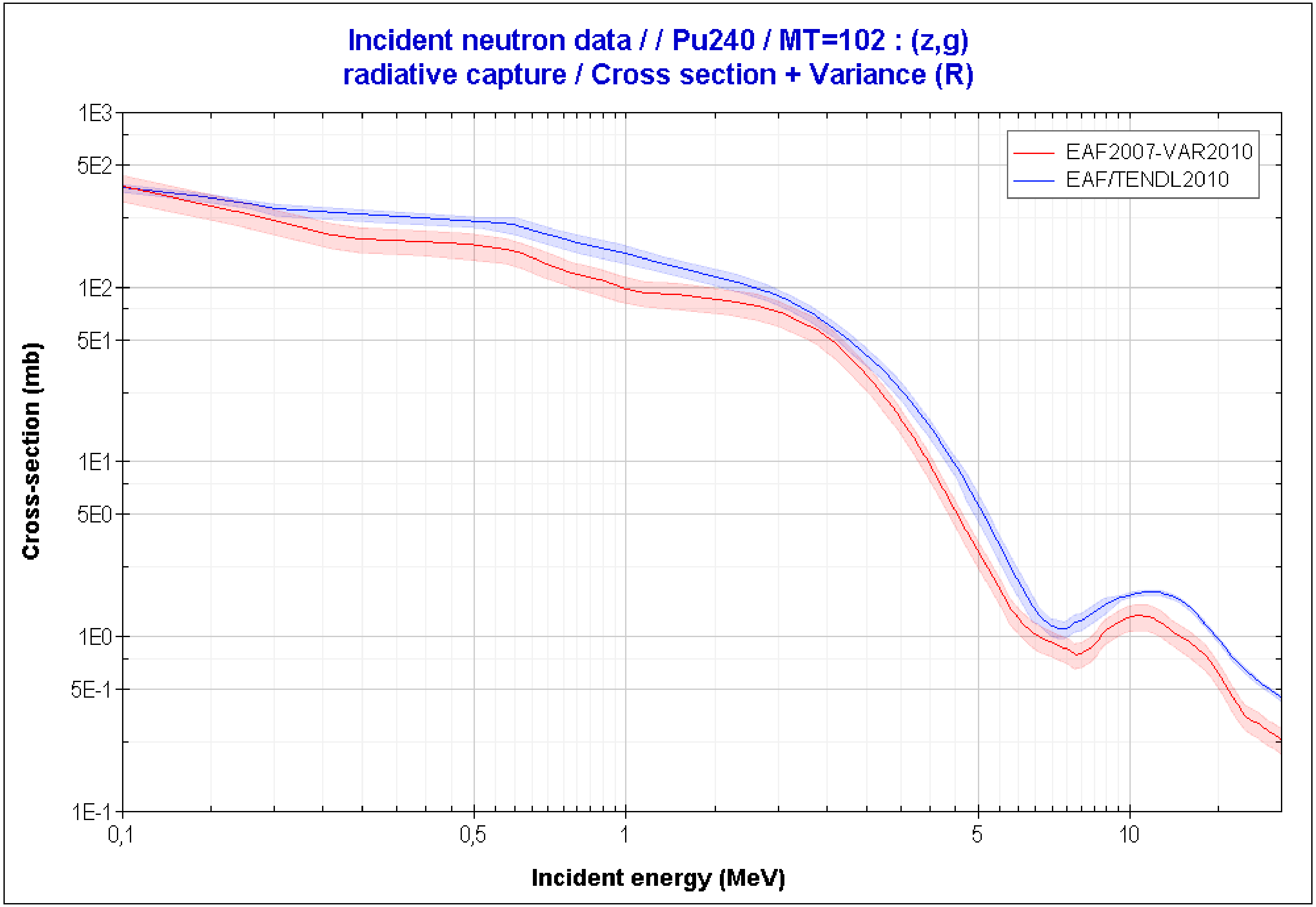
Processing $^{240}Pu(n,\gamma)$ – EAF2007 vs TENDL2010/EAF



Processing $^{240}Pu(n,\gamma)$ – EAF2007 vs TENDL2010/EAF

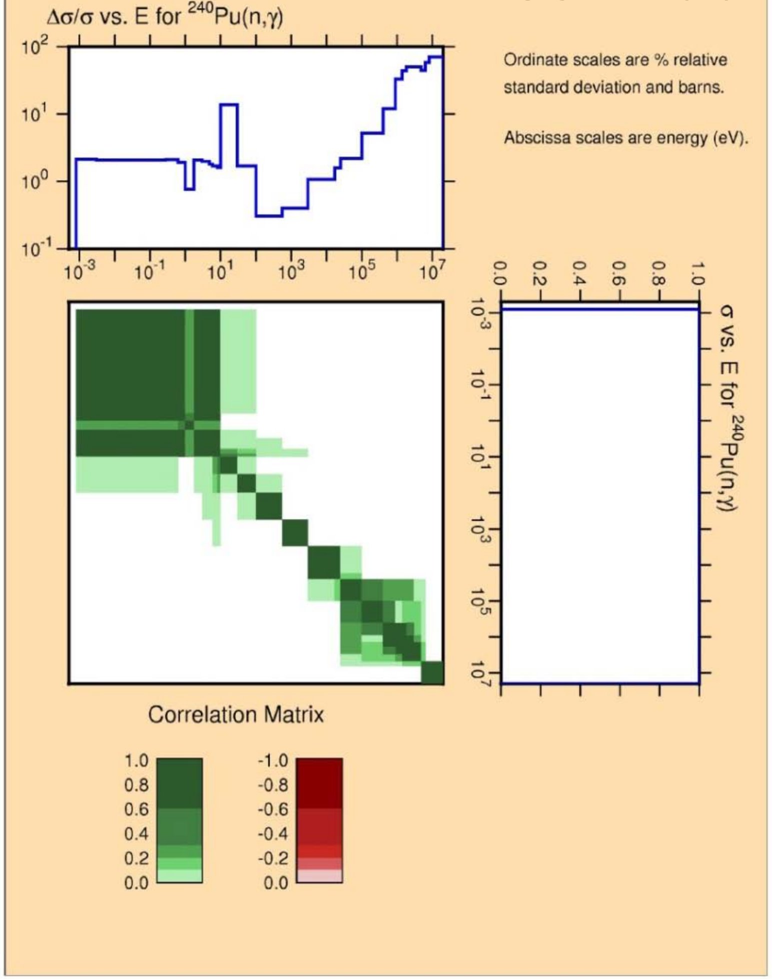


$^{240}Pu(n,\gamma)$ – EAF2007 vs TENDL2010/EAF

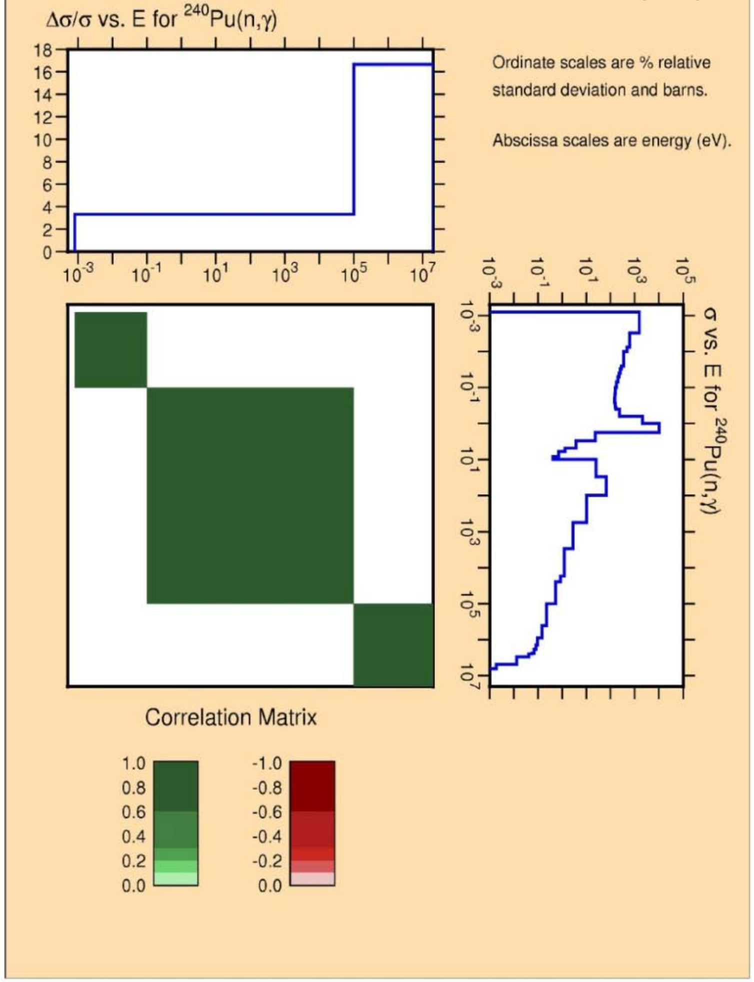


^{240}Pu(n,γ) Covariance Matrix in 44g

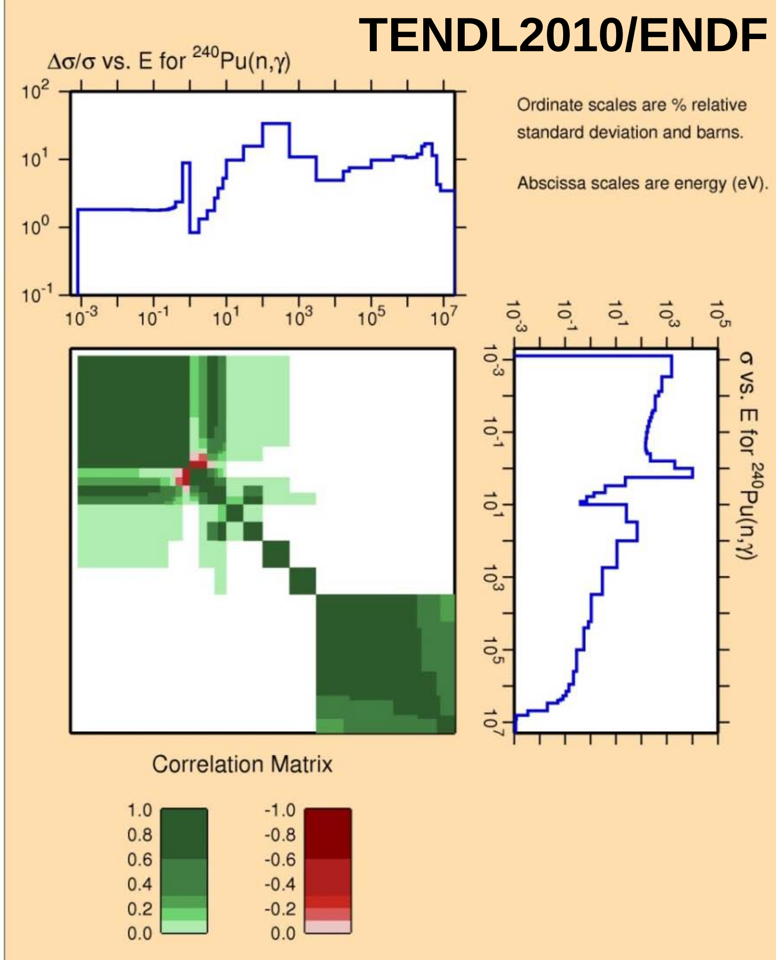
SCALE6.0



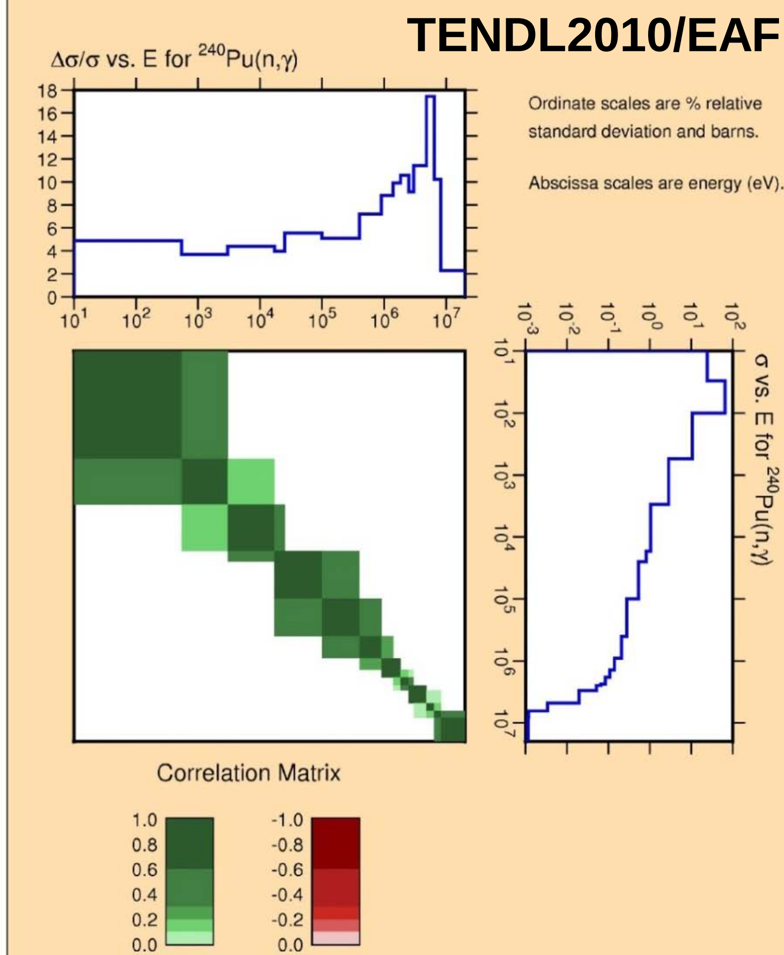
EAF2010



$^{240}Pu(n,\gamma)$ Covariance Matrix in 44g



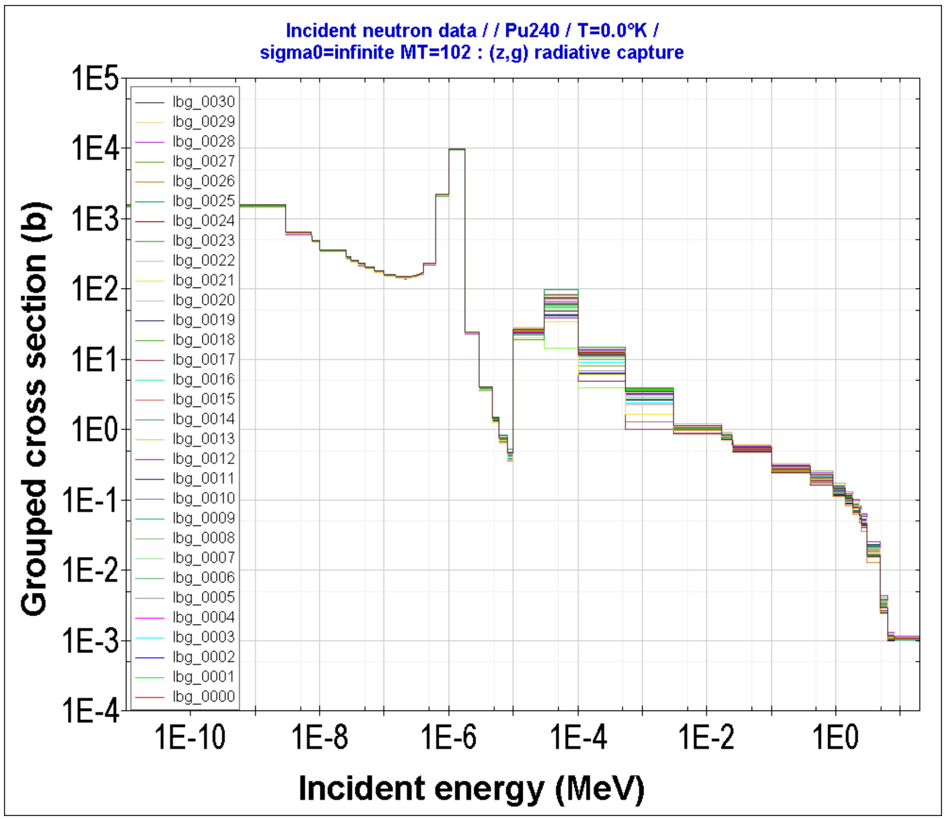
ENDF files (where MF32 and MF33 are used)



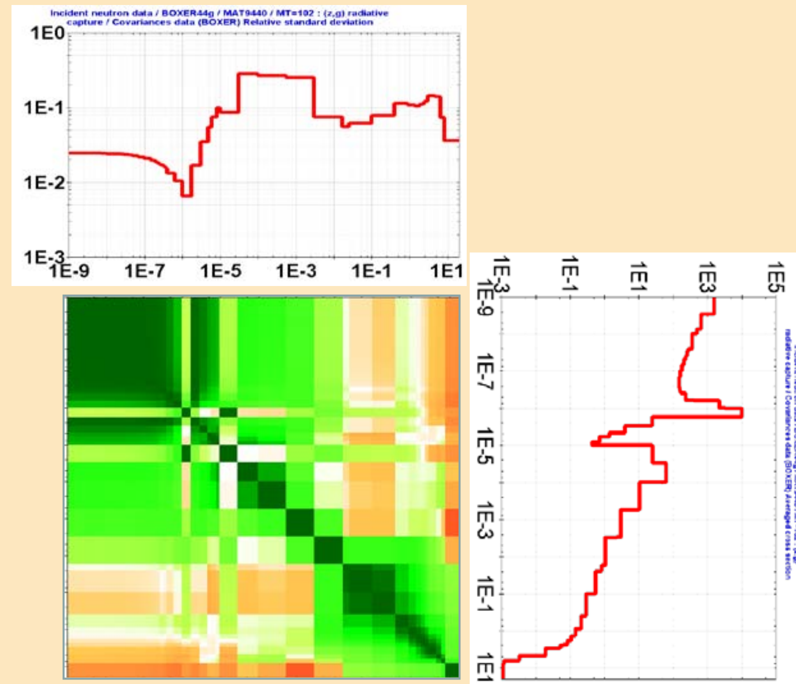
EAF uncertainties come from Talys (Optical model): no resonance info (no structure at low energy)

$^{240}Pu(n,\gamma)$ Covariance Matrix in 44g from RANDOM/EAF

How can we calculate the correlation matrix based on the random files?

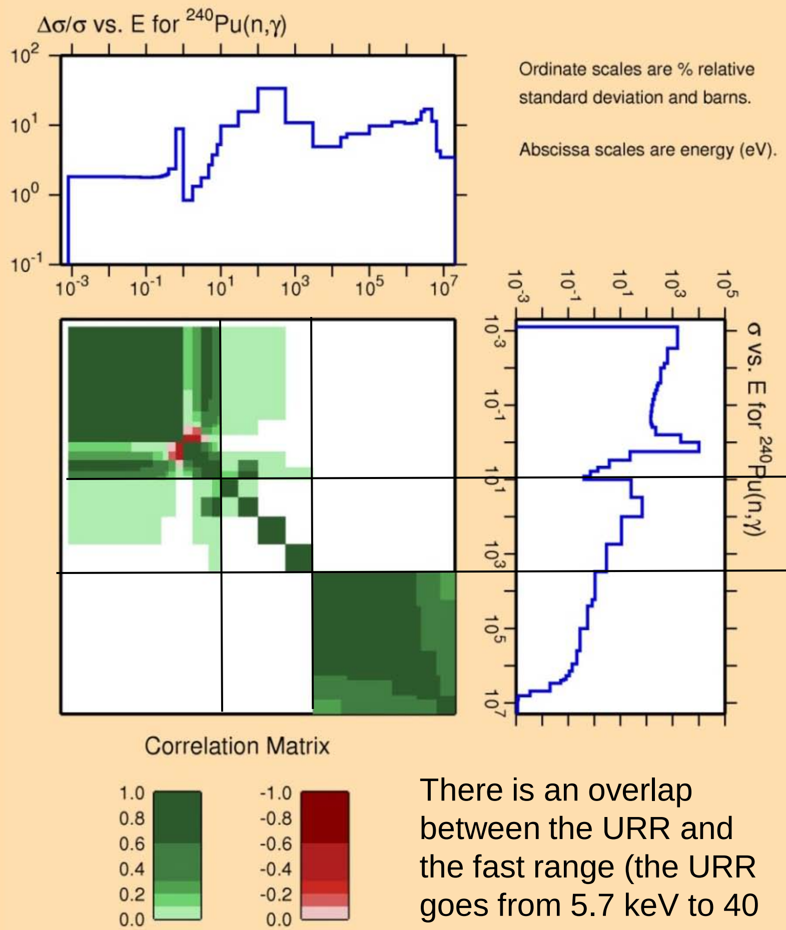


TENDL2010/RANDOM EAF files



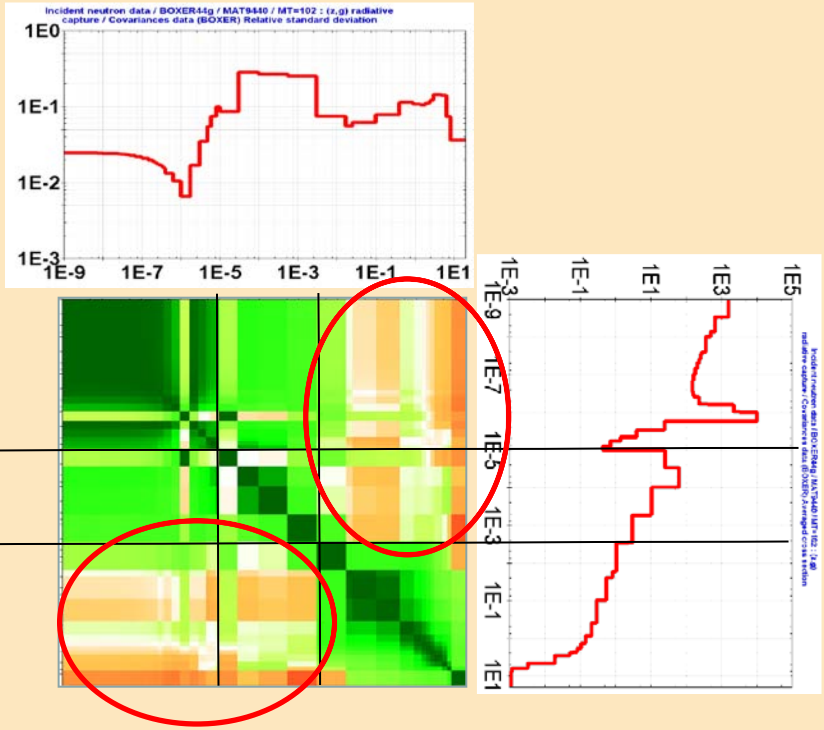
$^{240}Pu(n,\gamma)$ Covariance Matrix in 44g

TENDL2010/ENDF



There is an overlap between the URR and the fast range (the URR goes from 5.7 keV to 40 keV and the fast range start at 5.7 keV).

TENDL2010/RANDOM EAF files



Can this effect explain part of the differences between TMC (using random fiels) and S/U methodologies (using ENDF covariances)?

SUMMARY & CONCLUSIONS of PART II

- **TENDL2010 in EAF/ENDF**
  1) Improvements in Q&A. We have identify:
     - MT=18 and MT=102 with more than 10000 energy points
     - No uncertainties for isomeric/branching reactions
     - Format errors in EAF/UN & NJOY/ERRORR-URR (e.g. Pu240)
  2) Random Libraries
     - Differences between TMC and S/U should be identify

THANK YOU FOR YOUR ATTENTION!!

INDUSTRIALES
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